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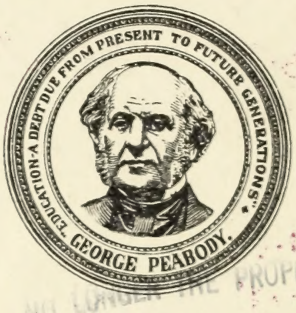

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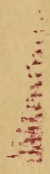

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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1301

Washington, D. C. March 30, 1925

REPORT OF THE NORTHERN GREAT PLAINS FIELD STATION FOR THE 10-YEAR PERIOD, 1913-1922, INCLUSIVE

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INTRODUCTION

The purpose of this report is to discuss briefly the experiments conducted at the Northern Great Plains Field Station, located in Morton County, N. Dak., 2 miles south of Mandan. No attempt is made to describe the experiments in detail, but rather to present the lines and scope of the work at the station and give a summary of results obtained from the various experiments. The projects are grouped and divided into three departments: Arboriculture, horticulture, and agronomy. The cooperative grazing experiment is a coordinate part of the agronomic work. The work and the results are reported separately by the men in charge of the respective departments.

The territory adjacent to the station, which is typical of a large area of western North Dakota, was primarily a livestock country.

[1] W. A. Peterson was superintendent of the station from the time it was organized until March, 1918. Max Pfaender was horticulturist from the time of the organization until September, 1919. F. E. Cobb assisted in the arboricultural investigations from June, 1915, to September, 1922, and from April, 1917, to October, 1919, inclusive, he was in charge of the work during the absence of Robert Wilson, who was on furlough in military service. Norman O. Henchel was assistant in arboriculture from June, 1917, to June, 1920. Arthur W. Schultz assisted in the agronomic work from May, 1915, until his death in 1917, and R. S. Towle assisted in the agronomic work from August, 1917, to March, 1920.

5381—25†——1

Grain farming was practiced to a limited extent in the early eighties, but not until recent years has it been developed as the principal type of agriculture. Livestock farming is still an important factor in the agricultural development of western North Dakota. This is especially true in sections having large areas of untillable land. Dairy farming is carried on in a limited way in several localities. Dairy farming is becoming an important factor in working out a permanent system of agriculture for the region.

The project creating the Northern Great Plains Field Station was started in the summer of 1912. During that year the site for the station was selected and plans for the construction of buildings and the organization of work were formulated and approved. In working out the plans, consideration was given the results obtained by similar stations operated by the Canadian Government and by the State agricultural experiment stations.

The station farm consists of 1,280 acres, 250 of which are under cultivation and devoted mainly to experimental work, while 640 acres of native sod are used for the cooperative grazing experiment.

The station buildings consist of an office, seed house, mess house, bunk house, two combined horse barns and implement sheds, and four residences. The residences are occupied by the station superintendent and the three men in charge of the departments. No provision is made for furnishing houses for men detailed at the station by cooperative offices or assistants or laborers. Several small buildings on the farm are used for various purposes, such as fumigating trees, soil work, and storage of special equipment and supplies.

CLIMATE

Climatic data covering a period of 48 years are available for this immediate region. The United States Weather Bureau has published the climatological data recorded at Bismarck, N. Dak., for the years from 1875 to 1920, inclusive.[2] Bismarck is located on the east side of the Missouri River, only about 5 miles distant from the Northern Great Plains Field Station at Mandan. Meteorological observations were begun at the field station during the summer of 1913, but the records for that year were incomplete and have not been used.

The temperature in this section reaches extremes in both winter and summer. The lowest temperature recorded in the nine years from 1914 to 1922, inclusive, was −45° F. in January, 1916, at Bismarck, and the highest was 110° F. in July 1921, at the field station. The average yearly maximum temperature at the field station for the 9-year period from 1914 to 1922, inclusive, was 52.6° F., and the average yearly minimum for the same period was 29.7°. The average maximum and minimum temperatures for the six months from April to September, inclusive, for the 9-year period were 74.7° and 47° F., respectively. The coldest months are January and February and the warmest July and August.

Table 1 presents data showing the frost-free period. The average number of frost-free days during the 10-year period from 1913 to 1922, inclusive, the period the field station has been in operation, was 134. The range was from 104 to 165 days. The average date of the

[2] United States Department of Agriculture. Weather Bureau. Summary of the climatological data for the United States, by sections. Reprint of Section 31, Western North Dakota. 14 p., map. [1922.]

last frost in the spring was May 13 and of the first in the fall September 24. The average number of frost-free days for the 48-year period from 1875 to 1922, inclusive, was 130. The average date of the last frost in the spring for this period was May 12 and of the first in the fall September 19.

TABLE 1.—*Frost-free period at the Northern Great Plains Field Station for the 10-year period, 1913–1922, inclusive*

Year	Killing frosts				Frost-free period (days)
	Last in spring		First in fall		
	Date	Temperature (°F.)	Date	Temperature (°F.)	
1913	May 6	32	Sept. 21	32	138
1914	May 13	32	Aug. 25	32	104
1915	May 18	31	Oct. 3	32	138
1916	May 15	32	Sept. 14	23	122
1917	May 26	28	Sept. 25	32	122
1918	May 11	23	Sept. 19	22	131
1919	June 2	32	Oct. 3	28	123
1920	Apr. 27	18	Sept. 28	28	154
1921	May 14	32	Sept. 30	31	139
1922	Apr. 25	29	Oct. 7	26	165
Average	May 13		Sept. 24		134

The wind movement at the station is measured by an anemometer placed 2 feet above the surface of the ground. The average wind velocity for the 9-year period from 1914 to 1922, was 6 miles an hour. The average for the months from April to September was the same. April and May are the months of highest wind velocity and July and August of lowest wind velocity. The highest velocity for any 24-hour period in the nine years was 24.2 miles an hour.

The evaporation from a free water surface during the warm season is shown in Table 2. Evaporation is highest in July and August and lowest in April and September.

TABLE 2.—*Evaporation from a free water surface at the Northern Great Plains Field Station for the 9-year period, 1914–1922, inclusive*

Year	Evaporation (inches)						
	April	May	June	July	August	September	Seasonal (April to September, inclusive)
1914	4.030	5.680	5.998	7.550	5.636	5.055	33.949
1915	4.850	3.855	5.377	5.420	5.467	3.647	28.616
1916	3.489	5.505	4.745	7.411	5.727	4.400	31.277
1917	2.183	6.437	7.175	8.695	7.021	4.171	35.682
1918	3.793	5.510	7.264	7.226	7.272	4.434	35.499
1919	3.739	6.022	7.258	9.168	8.057	5.347	39.591
1920	3.155	5.543	6.297	7.157	8.452	4.647	35.251
1921	3.638	5.147	7.324	8.899	8.524	5.730	39.262
1922	3.379	5.337	5.638	6.740	7.935	4.826	33.855
Average	3.584	5.448	6.342	7.585	7.121	4.695	34.775

TABLE 3.—*Monthly, seasonal, and annual precipitation at or in the vicinity of the Northern Great Plains Field Station for the 48-year period, 1875–1922, inclusive*

[Data in inches; T=trace. The records from 1875 to 1913, inclusive, were obtained by the United States Weather Bureau at Bismarck, N. Dak. Those from 1914 to 1922, inclusive, were obtained at the field station]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Seasonal, Apr. to Aug.	Annual
1875	1.13	1.32	2.06	4.22	3.40	5.02	1.54	2.89	1.85	2.37	1.33	0.39	17.07	27.52
1876	.78	1.45	3.27	2.77	5.74	1.24	1.48	6.55	5.61	.30	.86	.87	17.78	30.92
1877	1.64	.19	.77	1.32	4.15	4.60	2.52	.35	.11	.94	.40	.69	12.94	17.68
1878	T	.26	1.46	5.71	3.15	2.78	1.17	2.79	.67	1.45	.21	.58	15.60	20.23
1879	.15	.82	.58	2.60	3.67	4.97	4.27	2.69	.07	1.35	.16	1.28	18.20	22.61
1880	.30	.16	.69	3.65	2.76	2.32	2.02	4.82	.72	.27	.87	1.17	15.57	19.75
1881	.69	.78	.45	1.02	2.27	4.11	1.28	2.98	1.26	.51	.35	.06	11.66	15.76
1882	.23	.30	1.22	3.56	3.46	3.88	4.31	.30	1.74	1.44	.46	.43	15.51	21.33
1883	.25	.66	.38	1.57	1.15	3.84	1.32	.98	.04	3.88	.26	1.33	8.86	15.66
1884	.38	.87	.60	2.20	2.56	3.63	3.62	3.80	2.34	.92	.73	1.71	15.81	23.36
1885	.31	.36	.18	3.21	.92	2.39	2.41	1.62	.14	.54	66	.34	10.55	13.08
1886	.62	.54	.94	1.49	1.73	2.03	1.43	1.45	.38	.65	1.24	.76	8.13	13.26
1887	.95	.52	.78	1.52	2.19	.85	4.49	1.62	1.35	1.15	.11	.80	10.67	16.33
1888	.96	.44	.87	.11	.70	5.77	3.96	1.73	.33	1.02	.38	.24	12.27	16.51
1889	.50	1.48	.55	.26	3.35	1.03	2.01	.53	.48	T	.15	.69	7.18	11.03
1890	.80	.27	.49	.68	.57	8.40	1.14	.69	.98	1.37	.14	.22	11.48	15.75
1891	.05	.57	1.24	2.40	2.92	4.19	4.20	1.43	.87	.99	1.20	.44	15.14	20.50
1892	.29	.55	.95	3.23	1.79	3.49	3.13	2.40	.66	.86	.66	.16	14.04	18.17
1893	.73	.20	1.52	.69	1.26	4.33	1.48	.67	.18	.95	24	1.49	8.43	13.74
1894	.20	.04	2.27	3.40	.77	1.76	.30	.42	3.83	.87	.40	.06	6.65	14.32
1895	.89	.35	24	2.53	3.80	4.01	2.08	.40	.67	.08	1.60	.27	12.82	16.92
1896	.81	.31	.84	2.23	1.98	2.64	1.03	1.77	1.42	.48	3.10	.03	9.65	16.64
1897	1.11	1.32	.91	1.40	1.10	3.44	1.53	2.25	.30	.42	.25	.30	9.72	14.33
1898	.20	.48	1.00	1.12	2.65	1.21	1.64	1.35	.76	2.66	.16	.44	7.97	13.67
1899	.09	.18	.88	1.31	4.30	5.57	.45	.97	.06	.55	.47	.64	12.60	15.47
1900	.28	.30	2.24	.58	1.26	2.32	1.14	2.92	4.27	1.43	1.03	.11	8.22	17.88
1901	.03	.16	.96	.36	.04	5.17	3.24	1.01	1.47	1.89	.30	.96	9.82	15.59
1902	.05	.21	2.70	.26	3.20	3.63	2.54	1.84	.41	1.21	T	.10	11.27	15.95
1903	.82	.09	.12	.61	3.30	1.44	2.18	5.59	2.36	.27	.23	1.05	13.02	17.96
1904	.58	.72	1.09	1.38	.77	4.36	.90	.68	1.03	1.24	.03	1.39	8.09	14.17
1905	.31	.54	1.16	.07	1.87	5.61	3.24	1.71	.94	.30	1.36	.08	12.50	17.19
1906	.71	.06	.32	.85	5.37	4.78	1.15	2.04	.60	.32	1.38	.64	14.19	18.22
1907	1.01	.57	1.09	.67	1.98	3.63	4.32	.61	1.19	.80	.36	.32	11.21	16.55
1908	.24	1.07	1.35	1.73	2.89	2.29	.82	2.44	.59	1.81	1.60	.08	10.17	16.91
1909	.21	.36	.27	.84	4.43	2.19	2.41	4.77	.83	.78	.41	1.05	14.64	18.55
1910	.57	.57	.54	.59	.71	2.95	.93	1.26	2.66	.75	.14	.31	6.44	11.98
1911	1.50	.42	.31	1.18	1.18	2.73	1.13	2.72	2.26	.71	.78	.30	8.94	15.22
1912	.18	.08	.70	2.30	3.03	3.55	3.18	2.33	2.42	.94	T	.40	14.39	19.11
1913	.37	.03	.49	.55	1.99	2.06	2.72	.77	2.29	1.13	.16	.28	8.09	12.84
1914	.07	.05	1.89	1.55	3.57	10.68	1.35	1.89	1.24	.90	.31	.37	19.94	23.87
1915	.07	T	.30	1.11	4.98	6.32	6.48	.63	1.84	1.85	.34	.14	19.52	24.06
1916	.28	.09	1.88	.93	1.69	2.25	3.55	2.04	.92	.27	.07	1.10	10.46	15.07
1917	.28	.19	.35	1.87	.35	2.56	1.58	.89	1.97	.05	.03	.19	7.25	10.31
1918	.20	.11	.45	2.61	2.45	.68	2.47	2.03	.63	.27	.45	1.02	10.24	13.37
1919	.08	.80	.83	1.72	3.95	1.12	.85	1.22	.49	.98	1.19	.25	8.86	13.48
1920	.52	.20	1.21	.58	1.72	1.85	2.68	1.81	1.29	.25	.37	.21	8.64	12.69
1921	.18	.09	.79	2.59	3.05	.82	3.38	.25	1.58	1.39	.87	.24	10.09	15.23
1922	.28	1.55	.52	.66	2.05	3.43	3.17	.32	2.31	.64	1.60	.82	9.63	17.35
Average:														
48 years	.48	.47	.97	1.66	2.46	3.42	2.30	1.86	1.30	.96	.61	.56	11.69	17.04
9 years	.22	.34	.91	1.51	2.65	3.30	2.83	1.23	1.36	.73	.58	.48	11.53	16.16

Table 3 shows the precipitation for the 48 years from 1875 to 1922, inclusive. The records from 1875 to 1913, inclusive, are from Bismarck; from 1914 to 1922, inclusive, from the field station at Mandan. The winter precipitation at the station is measured by the rain gauge, which often fails to measure snow accurately. When there is reason to believe a measurement is inaccurate, the record of the United States Weather Bureau at Bismarck is substituted for the Mandan record.

Approximately 70 per cent of the total annual precipitation occurs during the growing season, from April to August, inclusive. Table 3 and Figure 1 show that the years 1916 to 1921, inclusive, were excep-

tionally dry. These were the driest consecutive six years during the 48-year period.

The 48-year average annual precipitation was 17.04 inches. The average annual precipitation for the 10-year period 1913–1922 was 15.83 inches. This is the period during which the field station has been in operation. For the 8-year period 1915–1922, for which crop yields are presented, the average annual precipitation was 15.20 inches. The quantity of precipitation during September, October, and November very often determines crop production in the following year. A very dry fall is usually followed by a season of low crop production; that is, if the soil goes into the winter dry the chances for good crops the following season are greatly reduced.

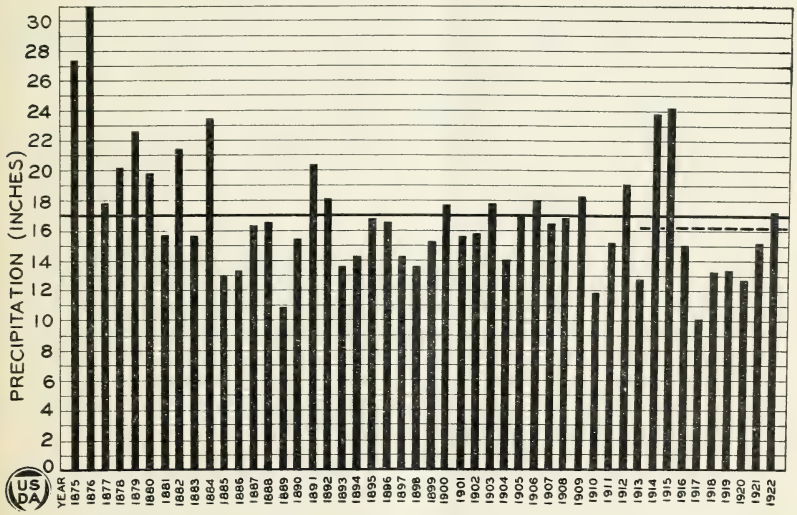

FIG. 1.—Diagram showing the annual precipitation at Bismarck and Mandan, N. Dak., for the 48-year period from 1875 to 1922, inclusive. The solid line indicates the average for the whole period. The broken line indicates the average for nine years at Mandan

SOIL [3]

The soil on the Mandan tract varies considerably, especially in texture. That on the plateau above the terrace on which the field-station buildings stand is a loam, the sand constituent being fine to very fine. On the experimental plats the soil is sandy loam. The experimental plats around the station buildings are located on a bench, consisting of a terrace, but the texture of the substratum is not light enough to affect the moisture relations in the soil horizons.

The normal mature soil of the region has a profile in which the illuvial horizon universally characteristic of the subsoil in humid regions is absent. The subsoil has about the same texture as the soil except in those spots where the texture of the former horizon is determined by geological factors rather than the processes of soil development. This latter condition would apply only to the soils on the terraces and not those on the uplands.

[3] This brief description and analysis of the soil was furnished by C. F. Marbut, in charge of Soil-Survey Investigations, Bureau of Soils

The color of the soils on the uplands, as well as that of the medium and heavier soils of the experiment plats, is best described as a strong dark brown, almost black. The dark-colored horizon in the virgin soil is about 8 inches thick, underlain by a brown horizon extending to a depth of about 2 feet. Below this lies the usual zone of accumulated carbonate of lime.

This soil lies on or near the western border of the true black earth of the United States. The color of the surface soil is dark enough to be placed in that group, but the 16-inch to 18-inch horizon of brown loam between the dark-colored surface horizon and the carbonate zone does not permit its correlation as a typical member of that group. It is also somewhat too dark to be placed in the zone of chestnut-colored soils. So far as existing knowledge of its characteristics will permit any decision as to its place in the general scheme of dry-land soils, it must be considered as a nontypical chernozem. In the scheme of classification used by the Bureau of Soils it is a member of the Williams series.

The composition of a sample taken from the plateau, locally known as the Custer Flats, 2 miles south of the station buildings, is shown in Table 4. The figures in this table show the total quantities of the constituents present.

The chemical analysis confirms the statement made above that the "good clay subsoil," universally present in the mature soils of the humid part of the United States and recognized by the farmers, is absent here. The analysis shows no concentration of either iron oxide or alumina in the subsurface, whereas the composition of the mature soils in the humid region invariably shows more or less concentration of this kind.

The content of lime, potash, and nitrogen is all good to high, and that of phosphoric acid is high.

TABLE 4.—*Chemical analysis of soil collected at the Northern Great Plains Field Station*

Analysis for—	Depth		
	0 to 7 inches	7 to 24 inches	24 to 36 inches
Silica, SiO_2 ---- per cent	70.31	70.74	60.71
Titanium dioxide, TiO_2 ---- do	.57	.66	.55
Ferric oxide, Fe_2O_3 ---- do	3.47	4.03	3.91
Alumina, Al_2O_3 ---- do	12.47	13.18	12.97
Manganese oxide, MnO ---- do	.087	.079	.055
Lime, CaO ---- do	1.12	1.08	6.69
Magnesia, MgO ---- do	.76	1.53	2.69
Potash, K_2O ---- do	2.52	2.34	2.28
Soda, Na_2O ---- do	1.05	1.10	.91
Phosphorus pentoxide, P_2O_5 ---- do	.17	.17	.17
Sulphur trioxide, SO_3 ---- do	.11	.09	.09
Ignition loss[1] ---- do	7.64	4.89	9.16
Nitrogen, N ---- do	.244	.11	.065
Carbon dioxide, CO_2 (from carbonates) ---- do	0	0	5.65
Water, H_2O at 110° F ---- do	2.33	2.30	2.50

[1] Nitrogen, carbon dioxide, and water are included in ignition loss and should not be added again in computing the totals, which approximate 100 per cent and are within the limits of error of the analyses.

ARBORICULTURAL INVESTIGATIONS [4]

The absence of trees on the farm lands of the Great Plains region is a factor of importance to the farmer in his effort to establish a comfortable and attractive home. Belts of trees not only improve the living conditions for the farmer and his family, but afford valuable protection to barns, yards, orchards, and gardens.

The severe climatic conditions, especially the limited rainfall and periods of drought, present difficulties to the tree planter that are unknown in the more favorable farming sections of the United States. A large number of the attempts to grow trees have been unsuccessful, and this fact has given rise to a widespread impression that tree planting in this region is not practicable. Investigation has shown that most of the failures were probably due to the use of species not adapted to the climatic conditions, to the lack of careful preparation of the soil before planting, and to neglect of cultivation after planting.

Experimental work in testing tree species at the station was started in 1914, and cooperative demonstrations with farmers at different points in the plains region in 1916. Both of these lines of work are still being carried on.

The following is an outline of the work now being conducted:

Experimental test plantings—
- Species testing blocks.
- Shelter-belt combination tests.
- Pruning, spacing, and methods of cultivation tests.

Cooperative shelter-belt demonstrations—
- Propagation of planting stock.
- Distribution of trees.
- Data from established shelter belts.

EXPERIMENTAL TEST PLANTINGS

SPECIES TESTING BLOCKS

Blocks of uniform size, containing in most cases 100 trees each, have been planted in pure stand with such species as give promise of being adapted to use in the Great Plains region. These blocks are intended to serve principally as tests of hardiness.

Table 5 shows the species that were in the testing blocks in 1922 and the year they were planted.

TABLE 5.—*Year of planting species of trees and varieties alive in 1922 in the testing blocks at the Northern Great Plains Field Station*

Scientific name	Common name	Block No.	Year planted
Abies balsamea	Balsam fir	22	1922
Abies concolor	White fir	29	1922
Acer ginnala	Ginnala maple	118	1915
Acer negundo	Box elder	111	1915
Acer platanoides	Norway maple	42	1922
Acer saccharinum	Silver or soft maple	102	1915
Acer tataricum	Tatarian maple	110	1915
Amelanchier canadensis	June berry, or shadblow	112	1916
Betula alba	European white birch	94	1916
Betula papyrifera	Canoe birch	95	1916
Betula populifolia	Gray birch	77	1915
Betula sp	Killdeer birch	44	1917
Caragana arborescens	Siberian pea tree	86	1915
Celtis occidentalis	Hackberry	81	1916

[4] By Robert Wilson, Associate Agronomist.

TABLE 5.—*Year of planting species of trees and varieties alive in 1922 in the testing blocks at the Northern Great Plains Field Station*—Continued

Scientific name	Common name	Block No.	Year planted
Elaeagnus angustifolia	Russian olive	17	1916
Fagus americana	Beech	43	1922
Fraxinus lanceolata	Green ash	79	1916
Fraxinus nigra	Black ash	73	1921
Juglans cinerea	Butternut	82	1916
Juglans nigra	Black walnut	75	1921
Juniperus virginiana	Redcedar	11	1916
Larix decidua	European larch	27	1915
Larix laricina	Tamarack	28	1916
Lepargyrea argentea	Buffalo berry	74	1918
Picea glauca	White spruce	20	1916
Picea glauca (var. Black Hills)	Black Hills spruce	25	1916
Picea engelmanni	Engelmann spruce	416	1922
Picea pungens	Colorado blue spruce	17	1916
Pinus banksiana	Jack pine	18	1917
Pinus contorta latifolia	Lodgepole pine	21	1921
Pinus ponderosa	Western yellow pine	19	1916
Do	do	24	1918
Pinus resinosa	Red pine	23	1920
Pinus sylvestris	Scotch pine	26	1916
Populus alba nivea	Silver poplar	50	1918
Populus angulata	Carolina cottonwood	65	1916
Populus balsamifera	Poplar	60	1916
Populus berolinensis	do	70	1916
Populus candicans	Balm of Gilead poplar	58	1916
Do	do	57	1916
Do	do	64	1916
Populus grandidentata	Largetooth aspen	35	1922
Populus nigra	Black poplar	69	1916
Populus nigra puskiniana	Poplar	61	1916
Populus nigra italica	Lombardy poplar	68	1916
Populus petrowskiana	Poplar	55	1916
Populus sp	Canadian poplar	59	1916
Do	Carolina poplar	56	1915
Do	Idaho poplar	53	1915
Do	Michael poplar	54	1922
Do	Northwest poplar	52	1915
Do	Norway poplar	51	1916
Populus sargenti	Western or Sargent cottonwood	62	1915
Do	do	48	1918
Populus tremuloides	Quaking aspen	66	1918
Populus wobsky	Poplar	63	1916
Prunus americana	Wild plum	84	1916
Prunus pennsylvanica	Pin cherry	80	1918
Prunus serotina	Black cherry	101	1916
Prunus virginiana	Chokecherry	120	1918
Pseudotsuga taxifolia	Douglas fir	30	1918
Pyrus baccata	Siberian crab	76	1918
Quercus macrocarpa	Mossy-cup or bur oak	93	1922
Quercus borealis	Red oak	89	1922
Rhamnus cathartica	Buckthorn	119	1918
Rhus typhina	Staghorn sumac	85	1918
Salix acutifolia	Sharpleaf willow	40	1915
Salix alba	White willow	39	1915
Do	do	47	1916
Salix daphnoides	Caspian willow	32	1921
Salix mackenzieana	Diamond willow	36	1915
Salix pentandra	Laurel willow	38	1915
Salix sp	Norway willow	31	1915
Do	Willow	33	1922
Do	Red laurel-leaf willow	45	1915
Salix vitellina aurea	Russian golden willow	37	1915
Salix vitellina britzensis	Bronze golden willow	46	1916
Sorbus americana	American mountain ash	41	1918
Do	do	78	1915
Sorbus aucuparia	European mountain ash	72	1915
Thuja occidentalis	Arborvitae	12	1916
Do	do	13	1921
Tilia americana	Basswood, or American linden	83	1918
Tilia europaea	Linden	87	1915
Ulmus americana	American elm	71	1915
Ulmus thomasi	Red elm	88	1916
Ulmus pumila	Dwarf Asiatic elm	103	1917

In addition to the varieties and species still under trial a considerable number have been tried and have failed. The failures were due mostly to lack of hardiness, but in some cases further testing may be

warranted. It is also desirable to test the same species from different sources. For these reasons, some of the species included in the following list of failures also appear in the list of those still under trial. The following is a list of species that have been planted in the species testing block and have not so far been successful:

Acer platanoides, Norway maple.
Betula alba, white birch.
Betula lutea, yellow birch.
Betula papyrifera, canoe birch.
Betula populifolia, gray birch.
Betula sp., birch.
Fraxinus americana, white ash.
Gleditsia triacanthos, honey locust.
Hicoria ovata, hickory.
Juglans nigra, black walnut.
Ostrya virginiana, hop hornbeam.
Picea abies, Norway spruce.
Pinus flexilis, limber pine.
Populus alba nivea, silver poplar.
Populus sp., poplar (S. P. I. No. 22447).
Quercus alba, white oak.
Quercus borealis, red oak.
Quercus coccinea, scarlet oak.
Quercus macrocarpa, bur oak.
Quercus palustris, pin oak.
Robinia pseudoacacia, black locust.
Salix acutifolia, sharpleaf willow.
Salix daphnoides, Caspian willow.
Salix sp., willow (S. P. I. No. 17737).

TABLE 6.—*Year of planting, spacing, number of rows, and arrangement of species of trees in 22 shelter-belt combinations grown at the Northern Great Plains Field Station*

Combination	Year planted	Spacing (feet)	Number of rows	Arrangement of tree species (from east to west)
No. 1	1915	4 by 4	12	Alternate rows of killdeer birch and green ash.
No. 2	1915	4 by 4	16	Two rows each of chokecherry, box elder, green ash, Carolina poplar, box elder, laurel willow, Russian golden willow, and chokecherry.
No. 3	1915	4 by 4	22	Wild plum, 2 rows; alternate rows of box elder and green ash, 8 rows; alternate rows of Carolina poplar and Russian golden willow, 8 rows; diamond willow, 2 rows; and wild plum, 2 rows.
No. 4	1915	4 by 4	20	Caragana, 2 rows; green ash, Carolina poplar, box elder, and laurel willow, 4 rows each; and caragana, 2 rows.
No. 5	1915	2 by 8	16	Caragana, box elder, green ash, Carolina poplar, box elder, laurel willow, Russian golden willow, and caragana, 2 rows each.
No. 6	1915	2 by 8	20	Caragana, 2 rows; alternate rows of green ash and box elder, 8 rows; alternate rows of Carolina poplar and laurel willow, 8 rows; and caragana, 2 rows.
No. 7	1915	4 by 4	8	Green ash and Russian golden willow, alternate rows.
No. 8	1916	4 by 8	2	Caragana and laurel willow, 1 row each.
No. 9	1916	4 by 8	3	Caragana, Carolina poplar, and laurel willow, 1 row each.
No. 10	1916	4 by 8	4	Caragana, Norway poplar, box elder, and laurel willow, 1 row each.
No. 11	1916	4 by 8	5	Russian golden willow, box elder, poplar, box elder, and laurel willow.
No. 12	1916	4 by 8	6	Russian golden willow, 1 row; alternate rows of poplar and box elder, 4 rows; and laurel willow, 1 row.
No. 13	1916	4 by 8	8	Caragana, 1 row; laurel willow, 1 row; and alternate rows of poplar and Russian golden willow, 6 rows.
No. 14	1916	4 by 8	10	Laurel willow, 2 rows; alternate rows of poplar sp. and box elder, 7 rows; and Russian golden willow, 1 row.
No. 15	1916	4 by 4	18	Laurel willow, box elder, green ash, box elder, poplar, box elder, poplar, box elder, and laurel willow, 2 rows each.
No. 16	1916	4 by 4	9	Box elder, Russian golden willow, box elder, poplar, box elder, green ash, box elder, laurel willow, and box elder. (Trees in rows 1 and 9 are 2 feet apart.)
No. 17	1916	4 by 4	4	Caragana, box elder, green ash, and laurel willow. (Trees in rows 1 and 4 are 2 feet apart.)
No. 18	1917	6 by 12	6	Box elder, green ash, dwarf Asiatic elm, northwest poplar, killdeer birch, and sharpleaf willow.
No. 19	1917	4 by 4	10	Buffalo berry, sharpleaf willow, box elder, green ash, dwarf Asiatic elm, northwest poplar, killdeer birch, green ash, box-elder, and sharpleaf willow.
No. 20	1917	4 by 8	5	Buffalo berry, box elder, dwarf Asiatic elm, killdeer birch, and sharpleaf willow.
No. 21	1917	4 by 4	20	Buffalo berry, sharpleaf willow, red laurel-leaf willow, box elder, killdeer birch, box elder, green ash, box elder, northwest poplar, dwarf Asiatic elm, box elder, green ash, killdeer birch, northwest poplar, box elder, green ash, killdeer birch, red laurel-leaf willow, sharpleaf willow, and killdeer birch.
No. 22	1917	4 by 8	10	Buffalo berry, sharpleaf willow, killdeer birch, northwest poplar, dwarf Asiatic elm, killdeer birch, green ash, boxelder, red laurel-leaf willow, and killdeer birch. (Trees in rows 1 and 10 are spaced 2 feet apart.)

SHELTER-BELT COMBINATION TESTS

A series of 22 shelter-belt combinations has been planted, in which a number of tree species are arranged in different combinations and spacings. The object of these tests is to determine, in a general way, the ability of a given species to grow in direct competition with trees of the same or different species in adjacent rows.

Table 6 gives the details of the spacing, arrangement of species, and year of planting these shelter-belt combinations.

Trees in these shelter-belt combinations have not reached a size large enough to show any marked effect of the different spacing distances. In general, however, the wider spacings seem to produce the better growth.

Green ash growing in alternate rows with box elder does not do as well as where it is in competition with other species, the box elder showing a marked ability to outgrow the ash in both height and lateral spread of branches.

Several of the species, notably Norway poplar, Carolina poplar, laurel willow, Russian golden willow, and killdeer birch, have not proved hardy or drought resistant and have largely died out in most of the combinations.

TESTS OF PRUNING, SPACING, AND METHODS OF CULTIVATION

Shelter-belt combinations of both hardwood and evergreen trees have been planted in series where the kind and arrangement of the trees are identical, but the spacing and care are varied.

The details of the different units of the hardwoods in this experiment are shown in Figure 2. Each block consists of 10 rows of trees spaced and treated as indicated in the illustration. Beginning with the east row of each block, the arrangement of species is as follows: Buffalo berry, sharpleaf willow, box elder, green ash, box elder, northwest poplar, green ash, boxelder, red laurel-leaf willow, and Tatarian maple.

At the end of the fifth year of growth the trees are hardly large enough to show the effects of spacing except in the series planted 4 by 4 feet, where the trees have grown completely together and begin to show the effects of crowding.

Moderate pruning seems to have no detrimental effect as compared with no pruning, but decided damage is done by severe pruning.

The mulched blocks still compare favorably with the clean-cultivated ones, but the neglected blocks are rapidly dying out in certain places.

TEN-ROW BLOCKS IN PURE STAND

Four species, boxelder, green ash, northwest poplar, and sharpleaf willow, have been planted in pure stands in 10-row blocks. Each species occupies two blocks, one spaced 4 by 4 feet and one 4 by 8 feet. At the end of the fifth growing season the trees in the blocks spaced 4 by 4 feet begin to show the effects of crowding.

CONIFER COMBINATIONS AND SPACING TESTS

Two combinations of conifers have been planted, with three different spacings each. The arrangement of the species and the spacing in this experiment are shown in Table 7. The trees are not yet large enough to show any effects of close spacing.

TABLE 7.—*Spacing and arrangement of species in the six blocks of the conifer combinations and spacing experiment at the Northern Great Plains Field Station*

Block	Spacing (feet)	Arrangement of species from east to west
No. 1	2 by 4	Scotch pine, jack pine, western yellow pine, Scotch pine, jack pine, and western yellow pine.
No. 2	4 by 4	Do.
No. 3	4 by 8	Do.
No. 4	2 by 4	Black Hills spruce, western yellow pine, jack pine, Scotch pine, and Black Hills spruce.
No. 5	4 by 4	Do.
No. 6	4 by 8	Do.

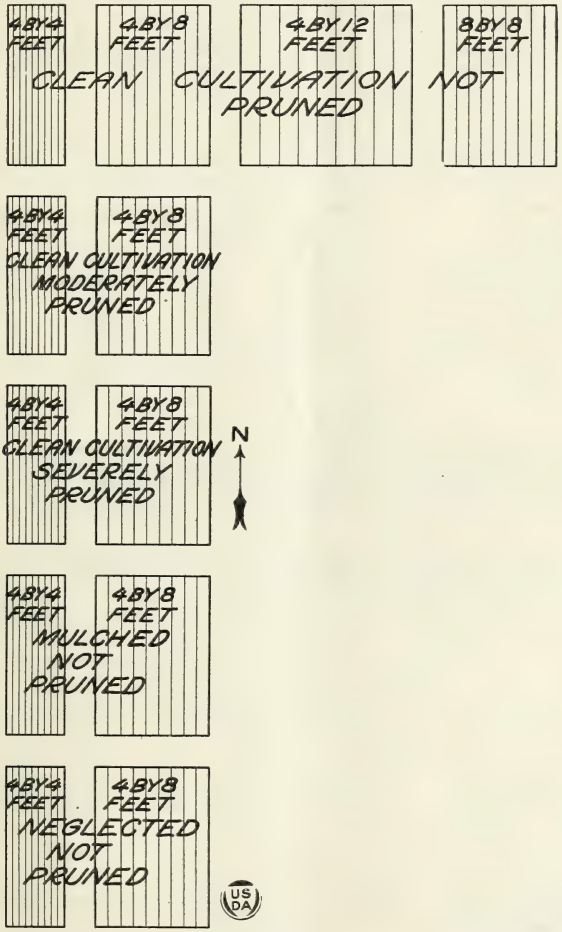

FIG. 2.—Plan of the pruning, spacing, and methods of cultivation experiments with hardwood shelter belts at the Northern Great Plains Field Station

COOPERATIVE SHELTER-BELT DEMONSTRATIONS

In 1915 a working cooperation with farmers living in the northern part of the Great Plains region was arranged, whereby the Department of Agriculture furnishes the trees, planting plans, and instructions for starting shelter belts on their farms. These shelter belts are designed to serve as demonstrations of the best methods of pre-

paring the land and planting and cultivating the trees. It is hoped that they will also serve to encourage farmers generally to purchase trees of hardy varieties and plant suitable shelter belts around their buildings.

The first demonstration plantings were made in 1916.

PROPAGATION OF PLANTING STOCK

A nursery is maintained at the station for propagating the trees for the demonstration plantings. Seed for the production of native tree species is collected locally, and as far as possible seed of introduced species is taken from blocks of trees growing at the station or on other plantings in the area, to insure hardiness.

Table 8 shows the total number of trees of all species used in demonstration plantings in the seven years from 1916 to 1922, inclusive.

TABLE 8.—*Total number of trees of all species used in demonstration plantings each year in four States in the northern section of the Great Plains*

Year	Montana	North Dakota	South Dakota	Wyoming	Total
1916	451,554	131,803	83,923	34,631	701,911
1917	226,870	84,559	31,931	14,340	357,700
1918	84,516	30,688	20,240	6,858	142,302
1919	79,906	62,146	16,651	3,859	162,562
1920	67,463	29,264	20,071	7,385	124,183
1921	60,636	29,632	15,949	5,348	111,565
1922	75,591	45,154	33,884	11,171	165,800
Total	1,046,536	413,246	222,649	83,592	1,766,023

DISTRIBUTION OF TREES

The accompanying map (fig. 3) shows the general manner in which the demonstrations have been distributed. The number of plantings made each year in the four states specified is shown in Table 9.

TABLE 9.—*Number of demonstration plantings of trees in the northern section of the Great Plains, showing the percentage of plantings in active cooperation at the end of succeeding years*

Year	Number planted	Percentage of plantings active at end of—						Number active in 1922
		First year	Second year	Third year	Fourth year	Fifth year	1922	
1916	633	94	80	69	59	50	45	282
1917	232	95	74	58	50	46	44	103
1918	75	81	57	49	47	43	43	32
1919	202	91	76	67	57	----	57	116
1920	92	97	88	78	----	----	78	72
1921	93	98	95	----	----	----	95	88
1922	181	97	----	----	----	----	97	176
Total or average [1]	1,508	94	79	66	56	49	58	869

[1] The numbers in this line are computed from the totals and are not the averages of the percentages above them in the column.

Failures have been due to one or more causes, the more common of which were improper planting, lack of care and cultivation, prolonged drought, and the owner leaving the farm. The years from 1917 to 1920, inclusive, were all years of severe drought, so the percentage of successful plantings gives encouraging evidence of the possibility of starting shelter belts.

Plantings for the years from 1916 to 1922, inclusive, were distributed to the different States as follows: Montana, 864, or 57 per cent;

North Dakota, 367, or 24 per cent; South Dakota, 211, or 14 per cent; and Wyoming, 67, or 5 per cent.

The kinds of trees used each year have varied. Species that have proved to be not adapted have been discarded, and new species have been added from time to time. Table 10 gives the number of trees of each species that has been planted to date.

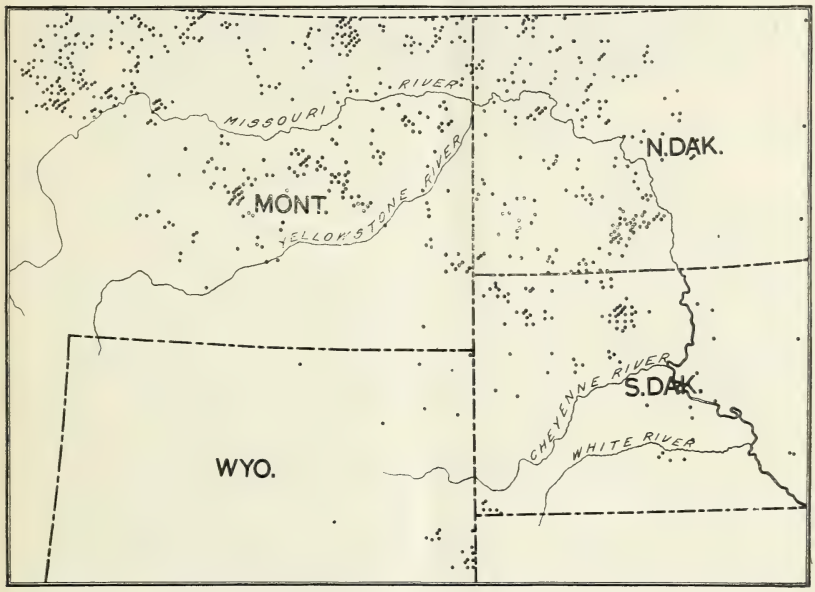

FIG. 3.—Outline map of the northern Great Plains region. The dots indicate townships in which cooperative shelter belts have been planted

TABLE 10.—*Planting stock of trees used in demonstration plantings in the northern section of the Great Plains, 1916–1922, inclusive*

Species and variety	Size	Total number of trees	Years used
Poplar:			
Norway and Carolina	9-inch cuttings	185,085	1916.
Do	1-year rooted cuttings	49,233	1916 and 1917.
Northwest	do	50,183	1920 to 1922, inclusive.
Willow:			
Laurel and Russian golden	9-inch cuttings	199,487	1916 and 1917.
Do	1-year rooted cuttings	232,019	1916 to 1919, inclusive.
Box elder	1-year seedlings	448,322	1916 to 1922, inclusive.
Green ash	2-year seedlings	305,913	Do.
Caragana	do	138,289	Do.
Elm:			
Dwarf Asiatic	1-year seedlings	3,452	1918 and 1919.
White	2-year seedlings	48,719	1917 and 1922.
Tatarian maple	do	4,226	1920 and 1922.
Buffalo berry	1-year seedlings	7,470	1920 to 1922, inclusive.
Chokecherry	2-year seedlings	7,464	1921 and 1922.
Russian olive	1-year seedlings	13,909	1922.
Black walnut	do	219	Do.
Pine:			
Scotch	2—1 transplants	18,386	1919, 1920, and 1922.
Western yellow	do	13,290	1919 to 1921, inclusve.
Jack	do	25,937	1919 to 1922, inclusive.
Spruce:			
Colorado blue	2—2 transplants	2,212	1920 and 1922.
White	do	5,411	1921 and 1922.
Black Hills	do	6,797	Do.
Total		1,766,023	

DATA FROM ESTABLISHED SHELTER BELTS

In the late summer of the year the trees are planted, farmers are furnished cards to report losses during the first growing season. Approximately half of the cards are returned. Table 11 gives the percentage of trees of each species that were alive at the end of the first season, as shown by the reports received.

TABLE 11.—*Percentage of trees of each species in the demonstration plantings in the northern section of the Great Plains alive at the end of the first year*

Species	Year						
	1916	1917	1918	1919	1920	1921	1922
Poplar (cuttings)	72.9						
Willow (cuttings)	68.8						
Poplar (rooted cuttings)	96.7						
Willow (rooted cuttings)	92.6	67.8	56.6	45.6			
Box elder	89.1	81.7	83.3	72.3	88.2	88.5	93.2
Green ash	93.7	85.0	77.2	68.5	79.9	66.9	96.1
Caragana	90.5		90.0	78.6		91.4	94.8
White elm		82.3					89.3
Dwarf Asiatic elm			[1]	[1]			
Tatarian maple							70.9
Buffalo berry						27.4	84.4
Chokecherry						91.0	86.7
Russian olive							77.8
Black walnut							[1]
Northwest poplar						89.6	94.9
Scotch pine					8.5		
Western yellow pine					9.7	32.3	
Jack pine					25.4	43.3	
Colorado blue spruce					46.0		
White spruce						26.9	
Black Hills spruce						23.4	

[1] Only a limited number of these species was used, and no reports were received.

SUMMARY AND CONCLUSIONS

During the period 1916–1922, 1,508 cooperative demonstration shelter belts were planted in the Great Plains areas of Montana, North Dakota, South Dakota, and Wyoming. Of this number 869 were growing at the close of the summer of 1922. A total of 1,766,023 trees were used in these plantings.

Of the tree species extensively tested, the following seem adapted to the climatic conditions generally prevailing: Box elder, green ash, white elm, and caragana.

The following species, which have so far been tested only in a limited way, give promise of being suitable for general planting: Northwest poplar, chokecherry, buffalo berry, Russian olive, Black Hills spruce, white spruce, blue spruce, Scotch pine, and jack pine.

Extensive tests of the following species show they are not adapted for general planting: Norway poplar, Carolina poplar, Russian golden willow, and laurel willow.

Careful preparation of the soil before planting to conserve moisture and work out grass and weeds is a prime requisite for successful tree planting. Clean summer fallow is the best tillage practice for this purpose.

Clean cultivation after planting is essential to the continued growth of young trees. Neglect in this respect for a single season is likely to result in serious damage to the trees.

Insect and animal pests may cause considerable damage unless precautions are taken.

With such species as box elder, green ash, and white elm, stock raised from seed procured from native trees has shown greater hardiness than that coming from more southern and eastern localities. Seed for propagating any species for planting in shelter belts on the northern Great Plains should come from a northern source.

The best spacing for trees in shelter belts has not yet been determined. Present data indicate that for the average planting site in the area, the 4 by 8 feet distance used in these demonstrations is too close. Further information is needed on this point.

The experience of these seven years of tree planting has shown conclusively that it is possible to start successfully a planting of trees on the average upland farm site in the northern Great Plains. Future investigation must show whether or not it is possible for such plantings to maintain themselves after they have attained their maximum growth.

Instructions to cooperators, and details of the plan of cooperation for the information of prospective cooperators, have been published in circulars, which may be obtained on request from the Northern Great Plains Field Station, Mandan, N. Dak. Further information is given in United States Department of Agriculture Bulletin No. 1113, and Farmers' Bulletin No. 1312.[5]

HORTICULTURAL INVESTIGATIONS[6]

Climatic conditions on the northern Great Plains are so severe that horticultural development has been slow and meager. Particularly is this true of perennials, such as fruit and ornamental shrubs and trees, which, to be successful, must endure the climate over a period of years. In general, success has been more marked in cities and towns where the trees are partially protected from wind, and where irrigation on a small scale is possible. Few farmers have succeeded in their efforts to grow fruit trees, ornamental trees, or shrubs, and farm life thus lacks one of the factors that tend to make it more desirable and attractive.

The climate of this region has been described on previous pages. The factors that make horticulture especially difficult are long, cold winters, droughts, severe winds, and short growing seasons.

Temperatures of −30° to −40° F. sometimes occur during the winter months, but there are other regions having temperatures approximately as low which have been far more successful along horticultural lines, so the difficulty is not one of temperature alone. Winterkilling has sometimes been very severe following dry autumns, which suggests the possibility that winter injury is often at least partially caused by drying out, or desiccation.

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[5] Wilson, Robert, and F. E. Cobb. Development of cooperative shelter-belt demonstrations on the northern Great Plains. U. S. Dept. Agr. Bul. 1113, 28 p., 15 fig. 1923.
Johnson, Fred R., and F. E. Cobb. Tree planting in the Great Plains region. U. S. Dept. Agr., Farmers' Bul. 1312, 33 p., 18 fig. 1923.
A copy of the latter bulletin may be obtained free by addressing the Department of Agriculture, Washington, D. C. The former may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 10 cents.

[6] By W. P. Baird, Associate Agronomist, and T. K. Killand, Scientific Aid, Office of Dry-Land Agriculture Investigations.

Drought at critical periods during the growing season causes severe losses, and often is responsible for poor stands the first summer after planting. Strong winds increase the amount of drying out in both winter and summer, cause damage to the foliage, blow much fruit from the trees, and if accompanied by high temperatures, sometimes cause scalding or burning of fruit and tender foliage. Protection from wind is almost essential to success with fruit. The average length of the frost-free period at Mandan is 134 days. This limits fruit to comparatively late-blossoming and early-maturing varieties.

The horticultural work at the station has had three objects: (1) To determine the varieties best adapted to the region; (2) to determine the horticultural methods best suited to the conditions; and (3) to create by plant breeding new or improved varieties better adapted than those already available. The work is reported under four groups or headings: Pomology, or fruit growing; olericulture, or vegetable growing; ornamentals and landscape gardening; and miscellaneous.

The horticultural work at the station began in 1913. This report covers the 10-year period, 1913–1922.

POMOLOGY

Success with fruits is extremely rare, and very few of the thousands of trees planted on the northern Great Plains have lived to bearing age. Standard varieties and methods used farther east have been found unsuited to the trying conditions. It is not likely that this region will ever be able to compete commercially with other localities better adapted to fruit growing, but enough has been done to indicate that it is both possible and worth while to grow some fruit for home use.

A considerable part of the horticultural work at Mandan has been devoted to fruit growing. Variety tests, cultural tests, and fruit-breeding work have been in progress.

VARIETY TESTS

Variety tests are always of importance in a new region, as one must know, first of all, what varieties to plant. Not only the varieties standard in the nursery trade but new productions from northern States and introductions from foreign countries are involved in the testing. A number of introductions made by the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture and by the Arnold Arboretum, Jamaica Plains, Mass., are being tested, and some give promise of being valuable additions to the present list of hardy fruits. Others are useful for plant breeding.

APPLES

A large number of the hardier varieties of apples and crab apples have been tested. Apples have not been generally successful from the standpoint of fruit production, but it is too early to draw definite conclusions, as the oldest trees are only 8 years old. Altogether about 2,000 apple and crab-apple trees, representing nearly 100 varieties, have been planted for variety tests or other purposes. About 10 per cent of the trees planted failed to start growth, and

about 40 per cent of those that started died within three or four years. The trees that survived appeared to become more hardy and resistant with age, but as yet none have produced what might be called a good crop of fruit. Crab apples generally have been more productive than standard apples.

The first variety-testing orchard was started in 1913, when 180 trees representing 12 varieties were planted. A stand of 166 trees was obtained, but only 55 survived the first winter. Through winter injury and damage by rabbits the remaining trees were in such poor condition that they were discarded in 1916, and the test was a failure notwithstanding the fact that such hardy varieties as Hibernal, Virginia, and Transcendent were included.

Another variety test was started in 1914, in what is designated as the "main orchard." It included more than 500 trees, set 16 by 24½ feet apart. The varieties were Hibernal, Yellow Transparent, University, Patten, Longfield, Malinda, Northwestern Greening, Peter, Okabena, Oldenburg (*Duchess*), Wealthy, Adno, Hibkee, and Sereda apples and Red Siberian, Yellow Siberian, Whitney, Minnesota, Transcendent, Florence, Hyslop, and Virginia crabs. Of 540 trees planted 502 started to grow, but only 213 remained in 1918, or 42 per cent of the number that started growth. As the showing was so poor and damage by rabbits so severe all remaining trees except a few crabs were discarded in 1918.

Detailed annual notes covering winter injury, growth, height, and fruitfulness have been taken for every tree in the above test, but such records are too extensive to be presented here. The Transcendent and Virginia crabs, survivals of the 1914 plantings, gave the best results. About 73 per cent of the former and 70 per cent of the latter varieties are now growing vigorously and producing some fruit.

A variety test was started in the "hillside orchard" in 1914 and 1915. Hibernal, Blushed Calville, Charlamoff, Anisette, Acid Repka (*Repka Kislaja*), Oldenburg (*Duchess*), Simbirsk, Antonovka, Gipsy Girl, Ostrakoff, and Volga Anis apples; and Lyman, Whitney, Phillips, Transcendent, Hyslop, and Virginia crabs being included. Less than half of those planted are now alive. Hibernal, Virginia, Lyman, and Transcendent seem to be the hardiest and most thrifty growers of the varieties tested, but most of the trees in this exposed orchard are in poor condition.

One of the most successful plantings was started in 1916. It consisted of 100 Hibernal apples and 100 Virginia crabs. Of the original number planted 88 Hibernals and 80 Virginia crabs are now alive, the former averaging about 6 feet in height and the latter about 8 feet. No apples and only light crops of crabs have yet been produced. It is planned to top-work to other varieties some of the trees in this orchard. This may increase fruit production by giving better pollination.

Variety tests have also been conducted under a system of close planting in hedgerows, one planting being made in 1918 and one in 1919. Standard varieties, for the most part, were used in the 1918 planting; whereas a number of Prof. N. E. Hansen's productions and a number of Canadian productions are being tested in the 1919 planting, which included more than 50 varieties of apples and crabs. About 50 per cent of the trees set in the 1918 planting and 73 per

cent of those in the 1919 planting are alive. The low percentage in the first planting is due to poor stands obtained the first summer. Some of the newer varieties of crabs in the 1919 planting, two Oldenburg (*Duchess*), and several Patten, have already borne fruit. Silvia, Beauty, Jenkins, and Dolgo appear to be among the more promising of the crabs, but this test has not gone far enough to permit definite conclusions.

About 30 apple and crab selections from the Minnesota Fruit-Breeding Farm were planted in 1921, good stands resulting.

About 50 selections from the South Dakota Agricultural College are being tested, but have not yet borne fruit.

In general, the variety testing of apples here has shown: (1) That only the hardiest varieties will survive; (2) that even when the hardiest varieties are selected poor stands often occur and fruit production is uncertain; (3) that some of the newer varieties from Canada and South Dakota seem to be promising; (4) that of the older varieties, Hibernal and Oldenburg (*Duchess*) apples and Virginia and Transcendent crabs have given the best results, but no variety has produced good crops of fruit; and (5) that while apples have been unsatisfactory to a large extent it is as yet too early to condemn them, especially if planted in protected places.

PEARS

Pears have been tested to a limited extent, but have generally shown a lack of hardiness and should not be planted except possibly where special protection is given. Flemish Beauty is the hardiest variety tested. Several varieties of pears have come through the last few winters without serious injury when grown in bush form in hedgerows and protected by a mulch.

PLUMS

Plums have been by far the most satisfactory of the tree fruits tested. *Prunus domestica* varieties and Japanese plums (*P. salicina*) are not hardy, so it is to the native *P. americana* or *P. nigra* selections or to hybrids between these hardy native plums and the more tender Japanese varieties, that one must look for success. Some crosses between the native sand cherry (*P. besseyi*) and both native and Japanese plums have done well. Hybrids between the Japanese plums and either native plums or native sand cherries are the finest and best in quality that can be grown on the northern Plains, but such hybrids are likely to be somewhat lacking in hardiness.

The first varietal test of plums was started in 1913 with Terry, De Soto, Wyant, Wolf, Hanska, Cheresoto, Opata, Sapa, and Sansoto varieties. Out of 85 trees planted only 41 were alive in 1916, and they were in such poor condition that all were discarded. Wolf, Wyant, and Sansoto gave the best results in this preliminary test. This first test with some of the hardiest varieties of plums and plum-sand cherry hybrids resulted in failure as complete as the preliminary test with apples and crab apples.

The main plum variety-testing orchard was started in 1914, the trees being set 13 by 16 feet apart. At that time 20 commercial varieties and 8 selections from the Minnesota State Fruit-Breeding Farm were included. Out of 260 trees planted in 1914 only 76 were

alive in the fall of the following year, and it has been necessary to do extensive replanting each year, as even the hardiest varieties are likely to kill out and show poor stands for the first few years after planting. Much better stands have been obtained from plantings made in later years. Of 160 plums planted in hedgerows in 1918, 141 were alive in the fall of 1922, and of 62 planted in 1919, 43 were alive in 1922. Better stands have been obtained in the comparatively heavier soil of the west field than in the very sandy soil where the main plum variety orchard is located.

The following notes on the several varieties are based on their performance at Mandan:

Aitkin (*P. nigra*).—Semihardy, has winterkilled badly when young; large attractive fruit of fair quality; midseason, light bearer; dwarf upright tree; subject to shot-hole fungus; only fair variety.

Cheney (*P. nigra*).—Semihardy to hardy; medium-sized attractive red fruit of poor to fair quality; midseason; fair bearer; upright tree.

Cheresoto (*P. besseyi*×*P. americana*).—Semihardy; medium-sized fruit of fair to good quality; midseason; fair bearer; low spreading tree or bush form.

Cikana (*P. besseyi*×Gold plum).—Semihardy; small, poor fruit, sour; of no value.

Compass (*P. besseyi*×Miner plum).—One of the hardiest; small fruit of good quality; early; heavy bearer. One of the most reliable varieties for the northern Plains.

Cree (*P. nigra*×Combination plum).—Semihardy to hardy; good-sized attractive sweet fruit of fair to good quality; very early; heavy bearer. A very promising variety.

De Soto (*P. americana*).—Semihardy to hardy; medium-sized fruit of fair to good quality; midseason to late; heavy bearer.

Emerald (*P. salicina*×*P. americana*).—Semihardy; fruit large with soft flesh, of good quality and pleasant flavor, poor keeper, sweet and juicy; late; heavy bearer. A good variety for home use, but fruit is liable to damage by early fall frosts.

Forest Garden (*P. hortulana mineri*).—Semihardy to hardy; medium-sized red fruit of fair quality, peculiar flavor; late; prolific. A good annual bearer.

Hanska (*P. americana*×*P. simoni*).—Not hardy; large fruit with firm flesh, very good quality; midseason; light to medium bearer. Not adapted to the northern Plains except in the most favorable situations.

Hawkeye (*P. americana*).—Semihardy; large attractive fruit of fair quality; late; light to medium bearer.

Jewell (*P. americana*).—Semihardy; medium to large attractive fruit of fair quality; late; medium bearer.

Mendota (*Minnesota No. 5*) (?).—Semihardy; large attractive fruit of good quality; midseason; light bearer.

"*Minnesota No. 6*" (?).—Semihardy; large attractive fruit of good quality; midseason; light bearer.

"*Minnesota No. 35*" (?).—Semihardy (?); large, red, attractive plum; midseason; medium to light bearer. A good plum if it proves hardy.

New Ulm (*P. americana*).—Semihardy to hardy; large, attractive, yellow to light red fruit of fair quality; late; medium bearer; low spreading tree.

Ojibwa (*P. salicina*×*P. nigra*).—Semihardy to hardy; medium-sized attractive red fruit, pointed at apex, fair to good quality; early; prolific. A promising variety for the northern plains.

Opata [*P. besseyi*×(*P. munsoniana*×*P. salicina*)].—Semihardy; small to medium fruit with small pit, good quality, but a little lacking in flavor; earliest plum; bears second year; very prolific; drought resistant. This plum is not as hardy as could be desired, but on account of its earliness, good quality, and heavy annual fruiting habit it is one of the most valuable for the northern plains.

Oziya (*P. salicina*×*P. americana*).—Semihardy; fruit of good size and quality, but ripens unevenly and drops badly; very early; prolific. A good plum for the home garden.

Pembina (*P. nigra*×*P. salicina*).—Semihardy (?); large attractive fruit of fair to good quality; midseason; light bearer; appears promising.

"*Penning seedling No. 3*" (*P. americana?*).—Semihardy (?); large attractive fruit of fair to good quality; late; light to medium bearer.

Red wing (*Minnesota No. 12*) (*P. salicina*×*P. americana*).—Semihardy (?); large attractive fruit of good quality; midseason; heavy bearer. This is one of the finest fruits grown at the station, but there is some doubt of its hardiness.

"*Richard*" (*P. nigra?*).—Semihardy to hardy; good-sized, attractive fruit; midseason; medium bearer; dwarf habit.

Sansoto (*P. besseyi*×*P. americana*).—Semihardy to hardy; similar to Cheresoto.

Sapa (*P. besseyi*×*P. salicina*).—Semihardy; small to medium-sized fruit of good quality, with dark-purple flesh and small pit; early, prolific; bears second year. This variety is one of the finest of the sand cherry–plum hybrids, is drought resistant, and generally a heavy bearer, although not as prolific as Opata. It is not as hardy as Opata, and this is its chief drawback. It has done best in bush form.

"*S. P. I. No. 33307*" (*Prunus* sp.).—Hardy; small green or yellow fruit of very good quality; early; light to medium bearer. This little plum is worth planting on account of its hardiness and superior quality, and because its flavor is so decidedly different from other plums tested. Its disadvantages are early blooming and its tendency to light crops. It should be of value in breeding work.

"*Seedling No. 2*" (*P. americana*).—Hardy; medium-sized, attractive, red, mottled fruit of fair to good quality; early; prolific bearer. This variety was propagated from a seedling orchard near Edgeley, N. Dak. It is an earlier, hardier, and better plum than most of the standard *P. americana* varieties and deserves wider testing in the area.

"*Seedling No. 5*" (*P. americana*).—Hardy; medium-sized fruit of the De Soto type, but earlier and larger; prolific bearer. Obtained from the same source as Seedling No. 2 and is also worthy of distribution. It is one of the most valuable of the *P. americana* varieties tested.

Stella (*P. salicina*×*P. americana*).—Semihardy; large attractive fruit of fair to good quality; midseason to late; light bearer.

Stoddard (*P. americana*).—Semihardy; large, fine, attractive fruit of fair to good quality; late; light bearer. Not recommended.

Surprise (*P. hortulana mineri*).—Semihardy; medium-sized attractive fruit of good quality; late; light bearer.

Terry (*P. americana*).—Young trees not hardy, having repeatedly winterkilled; older trees, semihardy; large attractive fruit of fair to good quality; midseason to late; prolific bearer. This is a fine plum, but it has been subject to considerable winterkilling at Mandan. The few trees that have reached a bearing age seem to become hardier as they grow older and bear heavy crops of excellent fruit.

Teton (*P. americana*).—Hardy; medium-sized to large attractive fruit of fair to good quality; late, prolific bearer. A good americana plum, but sometimes the fruit drops badly. Tree a vigorous grower.

Tonka (*Minnesota No. 21*) (*P. salicina*×*P. americana*.—Semihardy (?); large attractive fruit of good quality; midseason; medium bearer. A very good variety if it proves hardy enough to warrant general planting.

"*Training School Special*" (*P. americana?*).—Apparently hardy; attractive red fruit of medium size and good quality; midseason to late; medium bearer. This plum was propagated from an old orchard on the grounds of the State training school. It may be some named variety or a root sprout, but is better than most standard americana varieties.

Waneta (*P. salicina*×*P. americana*).—Semihardy; large attractive fruit with firm flesh and good quality; midseason; prolific bearer. This variety is one of our finest plums, but there is some doubt whether it is hardy enough to warrant general planting on the northern Plains.

Wolf (*P. americana*).—Semihardy to hardy; medium-sized attractive fruit of fair to good quality; midseason; medium bearer. One of the best of the standard americana varieties.

Wyant (*P. americana*).—Semihardy to hardy; medium-sized, fair quality, almost freestone fruit; late; prolific bearer. This variety has been a heavy annual bearer and is valuable for that reason.

Many other varieties of plums are under trial, but as yet there are not sufficient data to warrant comment on them. Results indicate that the following list of plums, arranged in the order of ripening, would furnish a continuous supply of fresh fruit from the first of August to the middle of September: Opata, Cree or Oziya, Sapa, Compass, "Seedling No. 5" or "Seedling No. 2," "S. P. I. No.

36607," Redwing or Waneta, Richard, Wolf, Sansoto or Cheresoto, Wyant or Teton, and Emerald. Most of the varieties in this list are hardy, but a few of the better quality, semihardy varieties of different types are included for the sake of variety and change.

PEACHES AND APRICOTS

These fruits have been tested on a small scale, but no hardy variety has been found. They should not be planted, except, possibly, where they are given special attention and the trees irrigated and covered with soil during the winter. A number of Chinese apricot and Chinese peach seedlings have proved semihardy and reached a bearing age, but their fruit is of no value.

CHERRIES

The common varieties of sour cherries, such as Montmorency, Early Richmond, Wragg, Ostheim, and Dyehouse, have been tested and found not hardy at Mandan.

In 1916, 25 trees, including 5 varieties, were planted, but only 10 were alive in 1920. Of nearly 40 sour-cherry trees planted at the field station, only 5 are alive. The oldest of these were planted in 1918. None have borne fruit.

By proper protection and careful attention, it has been found possible occasionally to raise sour-cherry trees to a bearing age on the northern plains. This has been done in a number of cases, but the general planting of cherries can not be recommended.

SAND CHERRIES

Sand cherries are found native throughout a large part of the northern plains. They are drought-resistant, hardy, prolific, and early bearers. Sioux, Tomahawk, and "Hansen No. 5" are the only varieties that have been tested for a series of years. Of the three, the Sioux is by far the best in quality, although not as large as "Hansen No. 5," or as prolific as Tomahawk. The Sioux is worthy of more extensive planting. Few, if any, fruits are as reliable on the northern plains, and sand cherries ripen when most other fruits are still green.

JUNEBERRIES

Success is the only variety that has been tested, and this is well worth planting in the dry-land fruit garden. The bush is hardy and generally a prolific bearer. The fruit is of good size and quality and very early as compared to most fruits. Success, however, is not as early as some of the native Juneberry selections.

GRAPES

Common varieties of grapes have failed to grow and produce fruit, even when covered with soil during the winter. Fifty-six vines, representing 15 varieties, were planted in 1913, but in 1914 only 7 remained, and these were discarded. A new variety test of 206 vines, including 30 varieties, was started in 1914. Only 93 of these vines survived the first winter, although covered with soil, and only 4 vines were alive at the end of the third winter. A third test was started in 1918 when 66 vines, representing 14 varieties, were planted in a protected place between rows of evergreens. These were covered with soil in November, but the 8 vines that survived the first winter were in such poor condition that they were discarded.

Varieties which failed in the above test include Hungarian, Dakota, Monitor, Suelter, Beta, Janesville, Moore, Worden, Concord, Campbell, Niagara, Delaware, Agawam, Clinton, Elvira, Martha, Brighton, Lindley, "Robert's Wild White," Alvado, Bacchus, Berckmanns, Elvibach, Etta, Faith, Grein Golden, Missouri, Riesling, and Presley.

The only partial success with grapes was obtained in the combination fruit patch planted in 1918, where 5 vines each of Alpha, Beta, Hungarian, Monitor, "Robert's Wild White," and Suelter were planted 8 feet from a row of plums on one side and 8 feet from a row of apples on the other. An addition of 5 Concord, 3 Beta, and 1 Worden was made in 1919; and 6 vines of Beta in 1922. Of these, 3 Alpha, 4 Beta (1918 planting), 5 Monitor, 4 "Robert's Wild White," 4 Suelter, 1 Concord, and 6 Beta (1920 planting) were alive in the fall of 1922. All of these varieties produced some fruit in 1922. Concord is too late to be of value. The quality of the other varieties is poor, but better than the average native grape.

Considering the many failures, it seems that none of the varieties tested can be recommended for general planting under dry-land conditions on the northern plains.

CURRANTS

Of all fruits tested at Mandan, currants are among the most reliable bearers. They are fairly drought-resistant, and generally hardy without winter protection. Nine varieties of red currants were under trial for the eight years 1915–1922. The yields varied from complete failures in some years to more than 3½ quarts to the plant (for North Star) in 1918. Yields of more than 2 quarts to the plant were not uncommon in favorable years. London Market and North Star are the most prolific of the varieties tested. London Market is the most dependable, but North Star yields better in especially favorable years. The average yields of the varieties tested for the eight years are given in Table 12.

Four varieties of black currants (*Ribes nigrum*), Naples, Victoria, Champion, and Lee, were grown for three years. None of these varieties yielded as heavily or bore as consistently as the best red varieties, and therefore their culture is not recommended. The European black currant (*Ribes nigrum*) is the most susceptible and dangerous host of white-pine blister rust and its propagation and culture should be entirely abandoned.

Varieties, such as Crandall, originated by selection from the native flowering currant (*Ribes odoratum*) do very well and are consistent bearers, even in dry years. Some promising selections have been made at the station and are being tested. It is likely that they will yield as well or better than the best red varieties.

TABLE 12.—*Varieties of red currants and their average yield per bush, as tested at the Northern Great Plains Field Station for eight years, 1915-1922, inclusive*

Variety	Yield (quarts)	Variety	Yield (quarts)
North Star	1.28	Fay	0.43
London Market	1.09	Cherry	.20
Red Cross	.72	Chautauqua	.04
Pomona	.68	Perfection	.05
Red Dutch	.65		

GOOSEBERRIES

This fruit has not yielded as consistently as currants, nor has it generally been as hardy or long-lived; still gooseberries have their place, and fairly good crops have been produced in favorable years. Plants in the variety tests generally have been grown without winter protection, but all varieties have suffered more or less injury in severe winters, and some have winterkilled badly.

The first variety test was started in 1913 with two plants of Melford and 10 plants each of Houghton, Downing, Carrie, and Josselyn. Carrie and Houghton gave the best results, producing a light crop in 1915, and about 1 quart to the bush in 1916. All varieties suffered severely during the winter of 1916–17 and were discarded in the summer of 1917.

In 1914 another test was started which included 20 plants each of Houghton, Josselyn, Downing, Carrie, Champion, Transparent, and Industry. Houghton produced a few berries in 1915, and more than a quart to the bush in 1916. Transparent and Carrie were the next best producers in 1916. Downing and Carrie were the best yielders in 1917, the former producing almost a quart to the bush. Winter injury was severe in 1917–18, and the 1918 crop was a failure. Josselyn, Carrie, and Champion each yielded about a quart to the bush in 1919. All varieties in this test were practically dead in 1920 and were discarded. The average yields to the bush for the four best varieties for the four years from 1916 to 1919, inclusive, were approximately as follows: Carrie, 0.56 quart; Transparent, 0.50 quart; Houghton, 0.48 quart; and Downing, 0.46 quart.

A third test, including 9 varieties, was started in 1918, but all varieties in this planting have been discarded except the Van Fleet, which produced a light crop in 1919, more than 1 quart to the bush in 1920, and 4½ quarts to the bush in 1922. The fruit of all varieties was scalded by hot winds in the summer of 1921. Carrie gooseberries planted at a considerable distance from the Van Fleet test in the same year (1918) produced 2 quarts to the bush in 1922, or less than half as much as the Van Fleet.

In general, Carrie, Transparent, Houghton, and Van Fleet have ranked among the hardiest varieties and most consistent yielders. The fruit of the Van Fleet is the largest and best of the four.

RASPBERRIES

This fruit does not thrive without irrigation in the dry climate of the northern plains. Prolonged droughts in May and June, when the fruit is forming, often cause complete failures. Fairly satisfactory yields were obtained at the field station in 1916 and in 1922, but the crop was a failure in other years.

With the exception of a native black raspberry, which is semihardy without protection, all varieties require winter protection. This is generally afforded by laying the canes down and covering them with soil.

The first variety test was started in 1913, but there is no record of this test after 1915, up to which time no fruit of any consequence had been produced.

Another more extensive test was started in 1914 and continued until 1920, when the varieties had become so badly mixed by sucker-

ing that the planting was discarded. The only crop worth harvesting was produced in 1916, the best varieties yielding more than a quart to the plant.

A third test was started in 1921. To reduce mixing through suckering, the varieties were planted in blocks instead of in rows. This planting produced a fair crop in 1922, although yields ran considerably less than a quart to the plant.

Red varieties in this trial included Cuthbert, Eaton, Empire, Herbert, Minnetonka, King, Latham, Loudon, Marlboro, Miller, "Minnesota No. 1," Perfection, Ranere (*St. Regis*), Sarah, Sunbeam, and Welch. The four of these varieties that appear to be among the most promising are Loudon, King, Latham, and Sunbeam. The last is rather small, but is drought resistant and shows up well in a dry year. Latham is superior in size and quality but is not as prolific as Loudon or King.

Black and purple varieties tested include Cardinal, Cumberland, Gregg, Kansas, Royal Purple, and Tye. Cardinal and Cumberland have given the best results, the former producing more than a quart to the bush in 1916. Black raspberries generally have not been as prolific as the red ones, and they are more difficult to handle.

BLACKBERRIES AND DEWBERRIES

Varieties of blackberries tested include Ancient Briton, Eldorado, Green, Rathbun, Snyder, Stone, Star (or Wonder), La Grange, and Joy. No stand of the last three varieties resulted. Blackberries were handled in the same way as raspberries, but none of the varieties proved hardy, and none produced fruit of any consequence.

Lucretia was the only dewberry tested. It was not hardy and failed to produce fruit.

The results indicate that blackberries and dewberries should not be planted on the northern plains, at least not under dry-land conditions.

STRAWBERRIES

Strawberries have been unreliable and generally poor yielders at the field station. Moisture is perhaps the chief limiting factor, as most varieties come through the winter without severe injury if protected with a good straw mulch.

The varieties tested include Dunlap, South Dakota, Warfield, LaBon, Trebla, Americus, Haverland, Bederarena, Progressive, William Belt, Minnesota, Minnehaha, Easypicker, Duluth, and a number of Minnesota and Ettersburg numbered selections. Dunlap Easypicker, and South Dakota have been the most reliable of the June-bearing varieties, while Duluth (Minnesota No. 1017) has been the best ever-bearing variety.

The results with strawberries indicate that planting should be limited unless there are some facilities for irrigating.

CULTURAL TESTS

After the hardiest varieties of fruits have been selected, one must know how to grow them and the cultural methods best adapted to the severe climatic conditions of the plains. Serious attention has been given to cultural problems, but it is rather difficult to obtain comparable results by the usual plat methods, owing to the difficulty

of obtaining a good stand of fruit trees and the tendency of a large number of trees to die during the first few years of the experiment. This interferes with the uniformity of the plats and increases the probable error of results. Replacements are not satisfactory, as they can not be compared accurately with the older trees.

CLEAN CULTIVATION, COVER CROPS, MULCHING, AND MANURING

A detailed cultural test involving 44 field plats was started in 1916 to study the effects of clean cultivation, cover crops, mulching with straw, and manuring on the hardiness of different kinds of plants. Clean-cultivated plats are worked often enough to keep them free from weeds. Plats growing a cover crop are given clean cultivation until about July 1, when oats are sown. Frequently the oats have been killed by frost before making a very good growth. Mulched plats are given clean cultivation throughout the summer and covered with straw to a depth of about 1 foot late in November. The mulch is allowed to remain until spring. Manured plats receive an application of well-rotted manure as a top-dressing every two years, each application being at the rate of about 20 tons to the acre.

Five classes of plants were included in this experiment: Plums, deciduous shelter-belt or forest trees, apples, ornamental shrubs, and herbaceous perennial flowering plants. The different treatments were duplicated for each class of plants. Owing to poor stands and other reasons, all have been discarded except the eight plats of plums. Results with apples and plums only will be reported here.

The work with apples included 16 plats. In eight plats they were on hardy Siberian crab roots, and in the other eight plats they were worked on the common French crab roots. The varieties used were Virginia, Hibernal, Oldenburg (*Duchess*), Patten, Longfield, Northwestern Greening, Malinda, Grimes Golden, McIntosh, Winesap, and Northern Spy. But few apples on the French crab roots remained alive in 1918, so these eight plats were discarded in that year.

TABLE 13.—*Survival of apples on tender and on hardy roots at the Northern Great Plains Field Station under different cultural treatments*

Treatment	On French crab roots		On Siberian crab roots	
	Planted in 1916	Alive in 1918	Planted in 1916	Alive in 1920
Clean cultivation	48	2	48	28
Mulched	48	16	48	35
Cover crop	48	2	48	31
Manured	48	4	48	24

More satisfactory results were obtained in the blocks with apples on hardy roots, but even here stands became so poor that these blocks were discarded in 1920. The number of trees planted and the number remaining under each treatment when the experiment closed are given in Table 13.

The best survival was on the mulched plats. The difference was especially marked in the apples on the tender French crab roots.

Observations on the individual trees show that mulching tended to increase winter resistance. The least winterkilling and injury were recorded on the mulched plats, and the greatest on those receiving clean cultivation, but the differences were not great where the apples were on hardy roots. The poorest survival of apples on hardy roots was in the manured plat.

Good stands of plums still remain in this experiment, and good crops are being produced. The effects of the different cultural treatments have not been marked; but, in general, trees in the mulched plats have been hardier than those of the same variety in other plats, and trees in the manured plats have suffered the greatest winter injury. Trees in plats growing a cover crop have averaged slightly hardier than trees growing in clean-cultivated plats.

The effects of the different cultural treatments on the yield and quality of fruit have not been marked. Manuring usually has resulted in a little better and larger fruit, but in slightly lower yields than other treatments. Mulching has given comparatively good yields and a good grade of fruit. There is but little difference in the results from clean cultivation and from a cover crop, but of late years there has been little difference in the treatments, as the cover crop has made small growth between the closely planted plums.

Cover crops have been used in other plantings at the field station, and observations indicate that they were of value at times in checking soil blowing and in holding snow. The results in most cases have not been very marked, and at present there are not enough experimental data to warrant recommendations. The evidence indicates that the desirability of growing a cover crop will depend largely on the season and the soil.

SPACING OF FRUIT TREES AND PLANTING SYSTEMS

Opinions vary as to what is the best spacing for fruit trees on the northern plains. Some advocate very wide spacing, because of the limited moisture. Others advocate close spacing in hedgerows or groups, for the sake of holding more snow and giving mutual protection. There are not sufficient experimental data yet to justify recommendations. Most of the apples at the field station have been planted in the square or rectangular system, from 15 to 20 feet apart. Plums generally have been planted from 12 to 15 feet apart.

In one planting rows of tree fruits were spaced 16 feet apart, with the trees 4 to 6 feet in the row. Small fruits were planted between the rows of tree fruits, making the rows 8 feet apart. In another planting the rows were spaced 12 feet, with the trees 4 to 6 feet in the row. It is rather difficult to compare the results of these plantings with those obtained by regular spacing, owing to differences in the ages of the plantings, varieties, and soil.

Better stands generally have been established, and the trees have suffered less winter injury during the first few years under the system of close planting, where more snow was held during the winter, and the trees received the benefit of mutual protection. Pears, apples of the Delicious variety, and a few sour cherries, in the close-planting demonstrations, suffered practically no injury in the winters of 1920–21 and 1921–22. In former years such tender fruits were seriously damaged when planted by a system of wide spacing. But

those two winters were unusually mild, so accurate comparisons can not be made.

In order to compare more accurately several planting systems, 7 experimental blocks of equal area were planted in 1921, the same varieties of apples and plums being used in all blocks. In blocks 1 and 5 plums are in rows 15 feet apart with the trees spaced 6 feet in the row, and apples are in rows 20 feet apart with the trees 6 feet in the row. In blocks 2 and 6 plums are spaced 15 feet square and apples 15 by 20 feet. In blocks 3 and 7 plums are planted in groups of four with the groups spaced 15 by 20 feet, and apples in groups of four with the groups spaced 20 by 20 feet. The four trees in each group are spaced about 2½ feet apart. In block 4 plums and apples are planted in the hexagonal system, the plums 12 feet and the apples 16½ feet apart. Standard varieties of known hardiness were used in this experiment. Apples are on the hardy *Pyrus baccata* roots, crabs on their own roots, and the plums on *Prunus Americana* roots. Notes will be taken to show the effects of the different planting systems on winter injury, growth, yields, quality of fruit, and the longevity of the trees. Good stands were obtained, except with one plum variety.

TREE FORM AND PRUNING

An experiment was started in 1915 with several sand cherry–plum hybrids to compare the results with these fruits grown in tree form and in bush form. Observations indicate that the bush form is the more satisfactory. These hybrids naturally grow in bush form.

No definite experiment has been carried out to compare high-headed and low-headed trees, but observations made on many trees indicate that low heading is the more desirable. Whether the tree should branch at the surface of the ground and grow in bush form or whether the lowest branches should be from 6 to 18 inches from the ground remains to be determined.

But little experimental work in pruning has been attempted, very light pruning generally having been employed with all tree fruits. Small fruits have been pruned in the standard way.

A few Opata and Sansoto plums planted in 1914 were pruned lightly, moderately, and severely in the autumns of 1920 and 1921. Both moderate and severe pruning reduced yields the following years, although the grade and size of the fruit were somewhat improved. As far as could be seen, the pruning had no effect on hardiness. Early results are decidedly in favor of the light pruning on account of the heavier yields.

To get more information on pruning and its relation to hardiness and fruit bearing six blocks of fruit trees were planted in 1921. Two blocks receive very light pruning, the trees being allowed to grow naturally except for removal of dead and broken limbs. Two blocks receive moderate pruning. In these blocks an attempt is made to select the main limbs and shape the tree. Further pruning consists of a light thinning out of the superfluous limbs to admit light and the removal of dead, broken, or interfering limbs. The trees in the other two blocks are pruned severely. They are treated the same as the moderately pruned trees except that thinning out of superfluous branches is a little more severe and part of the annual growth is

headed back each year. All pruning in these blocks is done before the trees start growth in the spring.

Varieties used in the pruning experiment are Whitney and Lyman crabs; Wealthy and Hibernal apples; and Wyant, Wolf, Waneta, Cheney, Opata, and Compass plums. Good stands of all varieties were obtained.

WINTER PROTECTION

Winter protection of some kind is essential to the growth of certain fruits on the northern plains. In other cases it may be desirable for a few years until the plants become established. Protection against mice and rabbits is generally necessary.

Mulching with straw or old manure is the most common form of winter protection that has been employed at the station. Straw mulching of apples and plums has been considered. A common practice has been to protect such tender fruits as pears and cherries by piling straw or old manure around the trunks of the trees, and experience indicates that winterkilling may be materially reduced in this way. A straw mulch from 6 to 8 inches thick has been found satisfactory for strawberries.

Protection can also be obtained by covering the plants with soil. This method has been found most satisfactory for raspberries, which commonly kill down to the surface of the ground if not protected. Grapes also have been brought through the winter in this way while unprotected vines were killed, but sometimes they have winterkilled even when covered with soil. Gooseberries and currants generally are able to survive the winter without such protection, although some varieties of gooseberries need covering. In the winter of 1914–15 covered gooseberries came through in good condition, while unprotected bushes were severely damaged. In general, however, unprotected gooseberries have yielded as well or almost as well as protected ones; if the hardier varieties are chosen, covering should not be necessary. Even tender varieties of trees bent over and covered with soil pass the winter without serious injury. Of course, such special protection with trees would be practicable only on a small scale.

Whitewash is being tested as a means of winter and early-spring protection. Whitewashed twigs heat up less during the warm sunny days of late winter and early spring, and as a consequence the dormant period is prolonged and the danger from late spring frosts is lessened. It may also lessen desiccation (drying out) of the twigs during the winter, which may be responsible for much winterkilling. Every third row in the pruning experiment is whitewashed, but it is too early to draw conclusions.

Protection from rabbits and mice generally has been accomplished with wood-veneer wrappers, tree paints, or poisoning. When the trees are grown in bush form it is difficult to protect by wrapping or painting, and poisoning has been found the most practicable method.

STOCKS AND TOP-WORKING

Hardy stocks are just as important as hardy varieties. Consequently, testing of different stocks for fruit trees has been an important line of work.

Apples have been tested on *Pyrus baccata*, French crab, Vermont crab, Paradise, Doucin, *Malus coronaria*, *Crataegus mollis*, Yankton

crab, and Minnesota crab seedlings. Of these, *Pyrus baccata* seems to be the most desirable. It is hardy and most apples readily form good union with it. Neither the common French crab nor the dwarf stocks, Paradise and Doucin, seem to be hardy on the northern Plains. Apples generally have not made good unions with *Crataegus mollis* or *Malus coronaria*, and stands from grafting or budding on these stocks have been poor.

Plums also have been grown on a number of different stocks, but the hardy native plum and sand cherry seem to be the only stocks that merit consideration. Both of these stocks are somewhat dwarfing in their effect. The sand cherry is especially noted for this, but plums on sand-cherry roots at the field station have generally grown as vigorously as or more vigorously than those on native plum roots. Observations indicate that trees on sand-cherry roots are sometimes more prolific than trees of the same variety on plum roots, but the grade of the fruit has often been superior on the plum roots. Suckering is more troublesome with sand-cherry roots, but with them there is no occasion to be in doubt whether a shoot is from the stock or scion. Both stocks are easy to grow, and both make good unions with the common varieties of plums grown on the northern Plains. They have been about equally satisfactory in the sandy loam soil at the field station.

Cherries have been budded on *Prunus pennsylvanica*, *P. besseyi*, *P. virginiana*, *P. americana*, and *Amygdalus davidiana*, but poor stands resulted, and none of the cherries lived for any length of time on any of these stocks. The ordinary stocks used for cherries are not hardy at Mandan, so no satisfactory stock for cherries has been found. However, hardy varieties of cherries have been lacking to test on the above stocks, so the stocks themselves should not be too severely condemned. It can only be said that the stands were poor on all stocks tried and that no stock has been tested which was satisfactory for the ordinary varieties of sour cherries.

Pears have been tested to a limited extent on Crataegus, Japan pear, Juneberry, mountain ash, *Pyrus baccata*, and pear seedlings. The stands have been poor and the scions generally winterkilled before the trees became established in the field. Pear scions tend to outgrow Crataegus and June-berry stocks, thus forming poor unions and top-heavy trees.

Top-working has not been successful, poor stands being the rule. Several attempts have been made to top-work the hardier varieties of apples with less hardy varieties of desirable quality, but these attempts have failed.

A few pears are now growing which were top-worked on June-berries in 1918, but the unions are generally poor. They have not produced fruit.

SITES AND LOCATIONS FOR ORCHARDS

Most of the orchard plantings at the field station are located on comparatively high, fairly level ground sloping toward the north and overlooking the valley of the Heart River. The air drainage is excellent, and sometimes fruit is produced when frost destroys the crops in the lower valleys.

Besides the plantings on this bench, three other special plantings have been made, one known as the hillside orchard and the other two

called coulee orchards. The hillside orchard occupies a north slope of a morainal hill on one of the highest and most exposed sites at the field station. Heavier soil is found here than in any other of the station orchards. The contour system of planting is used, the trees being placed in the center of plowed strips 20 feet wide which alternate with sod strips 30 feet wide. It was thought that excess rainfall would run off the sod strips and accumulate in the plowed land, thus increasing the water supplied to the trees. Seven rows of apples and crab apples were planted in 1915 and 1916.

In general, trees in the hillside orchard have given poorer results than trees of the same variety planted in the orchards with more protection. Most of the trees are now dead, and nearly all the others lack thrift and show the effects of the severe exposure. Very little fruit has been produced, and the orchard is practically a failure.

The coulee orchards were both planted in the spring of 1920, the trees for the most part being common varieties of apples and plums, and the purpose being to note the growth and productivity of the trees in the more or less protected coulees compared to trees of the same variety growing on the more exposed bench land. Growth in the coulees has been quite vigorous, and some of the sand cherry–plum hybrids have already produced excellent fruit. However, it is too early to draw conclusions as to the value of coulee planting. At present it seems to be very promising.

In this connection, a Wealthy seedling orchard planted in 1916 may be mentioned. A small coulee passes through the center of this orchard, and the stands in this coulee are good, whereas winter-killing has been very severe on the higher ground. The trees in the coulee are also larger and growing more vigorously.

FRUIT BREEDING

Variety testing and cultural experiments have their places in the development of fruit growing on the northern plains, but it is doubtful whether either line of work is of such fundamental importance as fruit breeding. Hardier varieties of all kinds of fruits are needed to build up a more successful northern Great Plains pomology. Much is to be looked for in the improvement of some of the hardy native fruits.

The following three methods of fruit improvement usually have been attempted at the field station: (1) Selection from seedlings, where only one or neither of the parents is known; (2) crossing by hand or with bees in the field; and (3) crossing under glass by hand.

The first method is the one most extensively used. A large number of seedlings of the different wild fruits are grown for selection purposes, and to study the tendency of the species to vary and break up into different types when grown under cultivation. This method has also been extensively used in growing seedlings of standard varieties of fruits, especially in cases where there seemed to be good opportunity for extensive natural crossing between desirable varieties. Some promising selections have been made from such seedlings.

The second method, crossing by hand or with bees in the field, has been attempted in a limited way. It was planned to grow in groups two varieties which were to be crossed, two trees of each variety in a group. The groups were to be covered with netting at blooming time and bees introduced to perform the crossing. Thus, all fruits

would be crosses if the varieties were self-sterile, and about half would probably be crosses if the varieties were self-fertile. This method was not found practicable, however, as poor stands were obtained and tender varieties died. There would also probably be some difficulty in handling the bees.

Crossing by hand in the field has been carried on in a limited way, but there is generally so much other work to do when it must be done that little time is available for doing it.

By far the greater part of the hand-crossing here has been done under glass in the greenhouse. Several hundred trees are growing in pots and tubs, and these are moved from their winter quarters in the root cellar to the greenhouse early in February. Most of the crossing is done in March, and the trees are kept in the greenhouse until the fruit is harvested. In this way it is possible to grow many varieties for breeding work that would not endure the climate outside.

Breeding work has been carried on with a number of different fruits, but apples and plums have received the most attention. In addition to these two fruits, work is now being carried on with cherries, grapes, and small fruits.

In the following paragraphs the character of the breeding or selection work that has been done with each of the fruits is briefly outlined:

Almonds.—A few almonds were grown in pots, and an attempt was made to cross them with *Amygdalus nana*, *Prunus tomentosa*, and *P. besseyi*. No fruits were obtained. Almonds have been discarded.

Apples.—A large number of Wealthy and other apple and crab-apple seedlings have been planted in the testing blocks for selection purposes. Some of the Wealthy seedlings have started to bear, and most of these have decided crab-apple characteristics. A few selections have been made for further trial. Seedlings of a number of species of Pyrus and Malus are also being grown for selection purposes. A large part of the hand-crossing work with fruits has been with apples and crab apples. About 50 different varieties have been used. *Pyrus baccata* has been used to a large extent as a hardy parent. None of the seedlings have yet borne fruit.

Apricots.—Chinese and Russian apricot seedlings have been grown in the seedling-selection blocks and some selections for ornamental purposes made. They bloom very early and are liable to be damaged by frost. The trees are semi-hardy. Some of the common varieties of apricots were potted and crossed with the Chinese apricot (*Prunus armeniaca*) and the *P. americana* varieties of plums. But few seeds were produced from these crosses, and none of the seedlings has borne fruit. No further breeding work is being done with apricots.

Blackberries and dewberries.—A few plants were potted, but no crosses were obtained. The potted plants have been discarded.

Buffalo berries.—Several thousand buffalo-berry seedlings have been set out for selection purposes. Variation has not been marked, and no selections have been made. Some apparently thornless buffaloberries were located in the wild in 1916, dug up, and transplanted to the station grounds. These plants failed to live, however, and no further effort has been made to locate thornless buffalo berries. There is some doubt as to whether these thornless specimens were *Lepargyrea argentea* or *L. canadensis*. A few buffalo berries were potted for inside crossing, but no seeds were obtained by this method. These trees have been destroyed.

Cherries.—Sour and sweet varieties of cherries have been potted, and attempts have been made to cross them with pin cherries, sand cherries, *Prunus tomentosa*, chokecherries, and *P. maacki*. Crosses have not been secured from the last two fruits. Plants obtained from the other combinations have not yet reached a bearing age.

Several hundred *Prunus pennsylvanica* seedlings have borne fruit, but although some show marked variation none have appeared good enough to be worthy of propagation.

Several thousand *Prunus besseyi* seedlings have been grown, and this hardy native fruit shows a very decided response to cultivation. Variations in the

flavor and size of fruit are marked, and a number of selections have been made for further testing.

About 38 *Prunus tomentosa* seedlings set out for testing in 1918 fruited in 1922. There was a wide variation in the size, flavor, and texture of the fruit on different bushes, and this fruit appears promising for breeding work. The bushes, however, are not entirely hardy in severe winters.

Several thousand chokecherry seedlings are now producing fruit. There is considerable variation in the time of ripening, and in the size, color, and flavor of the fruit, but none seem to be "chokeless," although some are much better than others in this respect. None of the seedlings have yet been propagated.

Seedlings of *Prunus maacki* have been grown to a limited extent, but this species appears to be valueless so far as fruit is concerned. The limbs are brittle and break badly, but the trees are very beautiful when in bloom.

Crataegus.—Seedlings of several species of Crataegus are growing at the station, but as yet none of the seedlings have appeared to be of any special value. Attempts have been made to cross *Crataegus mollis* with pears, Aronia species, and Juneberries, but these have failed.

Currants.—Seedlings of several common varieties of red currants and also seedlings of the native flowering currant of the Missouri Valley (*Ribes odoratum*) have been grown for selection purposes. Several selections of the red and about 25 selections of the flowering currant have been made and are being propagated for further testing. Some of the latter selections appear to be of value for the northern plains, as they are hardy and drought resistant, producing crops when most fruits fail. A few currants have been potted and some hand-crossing done, but without success.

Filberts and hazelnuts.—A few filberts and hazelnuts were potted for crossing work, but none of the potted trees lived to bearing age. A number of native hazelnuts have been planted, but stands have been poor and only a few are alive. These have not borne fruit.

Gooseberries.—Several thousand gooseberry seedlings have been grown for selection purposes, the seeds being obtained both from standard varieties and from native plants. Some seeds were obtained from groups where Houghton was planted with Industry, Chautauqua, Smith, and Lancashire Lad, so it is thought that some of these seedlings are crosses between Houghton and the varieties named. About 35 selections have been made, partly from native species and partly from seedlings of cultivated varieties. The best of these selections will be propagated for further testing. Gooseberries were also grown in pots and crossed by hand, but only a few seeds and no plants resulted from such work.

Grapes.—More than 10,000 seedlings of the native wild grape, and a few seedlings of cultivated varieties, have been grown. From these about 30 selections have been made for further testing. However, none of the selections from the wild grape appear very promising except as hardy material to cross with better varieties. A few vines have been grown in pots for hand-crossing work, but no seedlings have yet been obtained.

Highbush cranberries.—A few seedlings of *Viburnum lentago* and *V. americanum* are growing, but have not yet reached bearing age. No hand crossing has been attempted with this fruit.

June berries.—A large number of June-berry seedlings have been grown, and considerable variation in time of ripening, size and quality of fruit, and size of cluster has been observed. More than 200 selections have been made. It seems that this is one of the more promising of the native fruits for breeding work.

June berries have also been grown in pots and crossed with pears, quinces, Aronia species, *Pyrus baccata,* and Crataegus. Only a few seeds have been produced, however, and none have germinated. The potted plants have been discarded.

Peaches.—Several thousand Chinese peach seedlings have been grown, but were discarded as worthless except for ornamental purposes. The flowers open early and are likely to be killed by frost. The tree is semihardy. *Amygdalus davidiana, A. pedunculata,* and commercial varieties of peaches have been grown in pots and used for hand-crossing work. Some crosses made in 1917 between *A. davidiana* and common varieties of peaches were successful, but the resulting plants have not yet borne fruit. No other breeding work with peaches is being done.

Pears.—Seedlings of Japanese pears and standard varieties have been grown, but none were hardy, and all died before producing fruit. Pears in pots have been crossed with Chinese sand pears, Juneberries, *Pyrus baccata,* and Aronia, but only a few seeds have been produced, and none of the seeds germinated. Pear breeding has been discontinued.

Pecans and hickory nuts.—A few pecan and hickory trees have been potted, but no crosses were obtained, and the potted plants have been destroyed.

Plums.—More breeding work has been done with plums than any other fruit. Thousands of seedlings have been grown from the wild native plum and from cultivated varieties. A great deal of variation has been found within the *Prunus americana* species, and more than 50 selections have been made, many of which have been propagated and are undergoing a more thorough test to determine their value.

Many varieties of plums have been potted for hand-crossing work. Hardy *P. americana* and *P. nigra* varieties have been crossed or crosses attempted with Japanese plums, *P. simoni*, apricots, domestica plums, sand cherries, *P. tomentosa*, and with such hybrid plums as Waneta and Sapa. A hardy little yellow plum (S. P. I. No. 36607) has been crossed with Japanese plums. A few seedlings of known parentage have borne fruit, but as yet none seems to be of any special value.

Raspberries.—Seedlings of a number of cultivated varieties and of wild raspberries have been grown in testing blocks, but with the exception of a few seedlings of the native black raspberry all have been discarded. None of the discarded plants were hardy without winter protection, and none bore especially good fruit. Raspberries have also been potted and crossed by hand, but no seedlings have been obtained from such work. At present no breeding work is being done with raspberries.

Strawberries.—Several hundred strawberry seedlings were grown from standard varieties. Several selections have been made from these for further testing. There has been no hand-crossing work with strawberries.

Walnuts.—A few seedling black walnuts, and a few seedlings of *Juglans mandschurica*, have been grown, but no nuts have been produced. Several varieties and species of Juglans were potted for breeding work, but were discarded before reaching bearing age.

Cydonia.—Some attempts have been made to produce a hardy quince by crossing standard varieties with Pyrus, Malus, and Crataegus species. No seeds resulted, and quinces were discarded.

Elaeagnus.—*Elaeagnus angustifolia* and *E. multiflora* (*E. longipes*) were grown in pots and crossed with buffalo berries (*Lepargyrea argentea*), but no seeds were obtained. These plants have been discarded.

Cornus.—*Cornus siberica* and *C. stolonifera* were grown in pots and crossed, but no seeds were obtained. All Cornus plants have been discarded.

Aronia.—A few seedlings of *Aronia melanocarpa* were planted, but the fruit was of no value. But little variation within the species was observed. *A. melanocarpa* and *A. arbutifolia* were grown in pots and crossed with Amelanchier, Cydonia, Crataegus, and Pyrus species, but no fruits were borne. Potted Aronia plants have been discarded.

MISCELLANEOUS EXPERIMENTS IN HORTICULTURE

Nursery and seed-bed data, soil-moisture work, and horticultural cooperators are included under this heading.

NURSERY AND SEED-BED DATA

A quantity of data has been accumulated on handling seeds and growing seedlings, particularly of the different native fruits. Many notes have been taken regarding stands, growth, and hardiness in the nursery.

SOIL-MOISTURE INVESTIGATIONS

Some soil-moisture work has been done to determine the depth and the area of feeding of fruit trees, but without conclusive results. Because it is impossible to pursue this work with the intensiveness necessary to results, it has been discontinued for the time. The water content of the soil in the different plats of apples in the cultural experiment previously described was studied rather thoroughly. The only marked difference found was the greater dryness in the fall of the plat growing a cover crop.

HORTICULTURAL COOPERATORS

A limited number of fruit trees are being propagated for trial by horticultural cooperators. About 1,000 plum trees, mostly on sand-cherry roots, and about 300 apple and crab trees on *P. baccata* roots were ready to send out in the spring of 1923. Varieties were chosen which had given the best results at the field station.

Cooperators are chosen from those shelter-belt cooperators who have established satisfactory shelter belts and who are particularly interested in fruit growing. They must agree to care for the trees as directed, and to submit yearly reports of the results. Land must also be properly prepared. The regular square or rectangular system of planting trees will be used. By such cooperation, the more promising fruit varieties will be thoroughly tested under widely varying conditions; and, at the same time, the plantings will serve as demonstrations which, if successful, should encourage growing of fruit for home use on the northern plains.

ORNAMENTALS AND LANDSCAPE GARDENING

ORNAMENTALS

Under this class were included: (1) Deciduous and coniferous ornamental trees; (2) ornamental shrubs and vines; (3) hedges; (4) hardy perennials; (5) annual flowers; and (6) hardy and tender bulbs.

DECIDUOUS AND CONIFEROUS TREES

A comparatively large number of tree species were grown in nursery rows to ascertain their hardiness, usefulness, and general adaptability for ornamental purposes. This experiment was begun in 1913 and continued until 1919, after which date very little variety testing was undertaken and that was mostly with new plant introductions received from the office of Foreign Seed and Plant Introduction. This work with tree species was supplementary to the shelter-belt investigations and will not be treated in detail in this report.

SHRUBS AND VINES

Testing ornamental shrubs and vines in nursery rows, in the arboretum, in the ornamentation of the station grounds, and in larger plantings, began when the station was started in 1913 and has been continuous. More than half the shrubs planted have been killed out or frozen back so severely and repeatedly as to indicate that they are unsuited for this region.

The following is a list of the ornamental shrubs that survived three or more years:

Artemisia sp. (S. P. I. No. 32237).
Berberis thunbergi.
Caragana arborescens.
Caragana spinosa.
Cornus siberica.
Cornus stolonifera.
Cornus sanguinea.
Corylus americana.
Cotoneaster sp. (C. acutifolia?).
Crataegus crusgalli.
Crataegus pinnatifida.
Diervilla sessilifolia.
Elaeagnus angustifolia.
Elaeagnus argentea.
Euonymus alatus.
Euonymus americanus.
Forsythia suspensa fortunei.
Halimodendron halodendron.
Hydrangea paniculata grandiflora.
Lepargyrea argentea.
Lepargyrea canadensis.
Ligustrum amurense.

Lonicera chrysantha.
Lonicera floribunda.
Lonicera grandiflora rosea.
Lonicera morrowi.
Lonicera tatarica.
Lonicera tatarica alba.
Lonicera tatarica rubra.
Opulaster opulifolius.
Opulaster opulifolius aureus.
Philadelphus coronarius.
Philadelphus coronarius grandiflorus.
Rhamnus cathartica.
Rhamnus frangula.
Rhus cotinus.
Rhus glabra.
Rhus hirta.
Rhus hirta laciniata.
Ribes alpinum.
Ribes aureum.
Rosa blanda.
Rosa domestica.
Rosa rugosa alba.
Rosa rugosa rubra.
Rosa sp. (Persian Yellow).
Sambucus aurea.
Sambucus nigra.
Sambucus nigra laciniata.
Sambucus racemosa.
Schizonotus sorbifolius.
Spiraea billardi.
Spiraea bumalda.
Spiraea bumalda var. Anthony Waterer.
Spiraea sp.
Spiraea rosea.
Spiraea salicifolia.
Spiraea thunbergi.
Spiraea tomentosa.
Spiraea vanhouttei.
Spiraea sp. (native).
Symphoricarpos sp.
Syringa amurensis (S. P. I. No. 38828).
Syringa emodi.
Syringa japonica.
Syringa josikaea.
Syringa chinensis.
Syringa villosa.
Syringa vulgaris.
Syringa vulgaris alba.
Tamarix africana.
Tamarix pallasi (S. P. I. No. 34804).
Tamarix sp. (S. P. I. No. 35261).
Viburnum dentatum.
Viburnum lentago.
Viburnum opulus.
Viburnum opulus sterile.

The following species of ornamental shrubs, tested at Mandan during the period from 1913 to 1922, inclusive, did not survive as long as three years:

Amorpha canescens.
Amorpha fruticosa.
Buddleia davidi superba.
Calycanthus floridus.
Calycanthus occidentalis.
Ceanothus americanus.
Celastrus sp. (S. P. I. No. 39736).
Chaenomeles (Cydonia) japonica.
Colutea arborescens.
Corylus avellana.
Cotoneaster ignava.
Cotoneaster simonsi.
Cytisus maderensis.
Deutzia (Pride of Rochester).
Deutzia gracilis.
Deutzia scabra candidissima.
Diervilla Eva Rathke.
Diervilla florida.
Exochorda racemosa.
Forsythia sp.
Hibiscus syriacus.
Hydrangea arborescens.
Hypericum moserianum.
Laburnum anagyroides.
Ligustrum obtusifolium (L. ibota).
Lonicera spinosa alberti.
Lonicera periclymenum belgica.
Lonicera sinensis.
Rhus copallina.
Ribes atrosanguineum.
Rosa multiflora japonica.
Rosa setigera.
Rosa sp., assorted hybrid perpetuals, climbing roses, and Rugosa hybrids.[7]
Stephanandra incisa.
Symphoricarpos albus.
Symphoricarpos orbiculatus.
Syringa sp., assorted named hybrid lilacs.[8]
Tamarix amurensis.
Tamarix gallica.
Tamarix indica.
Tamarix juniperina.
Tamarix odessana.
Tamarix sp. (S. P. I. No. 35261).
Viburnum acerifolium.
Viburnum lantana.
Viburnum opulus nanum.
Viburnum tomentosum.
Vitex agnus-castus.

[7] There were three successive rose tests. A number, with protection, survived the first winter and bloomed sparingly the second summer, but they were generally so weakened that only a very few were alive the second spring, and were discarded.

[8] This was eastern stock, and undoubtedly budded on privet. If on its own roots or on hardy stock it might prove more successful.

Only a few species of vines were tested, and most of them proved entirely hardy. Those included in the test were:

Clematis virginiana
Humulus sp.
Lonicera flava.
Lonicera sp. (killdeer honeysuckle).
Parthenocissus quinquefolia.
Parthenocissus quinquefolia engelmanni.

HEDGES

A number of kinds of trees and shrubs were set out in hedgerows of various lengths 10 feet apart, 1 to 3 feet apart in the row. With the exception of three, all were planted in 1915. Most of them are still growing. The most successful ones were Spiraea, Syringa, Lonicera, Elaeagnus, Rhamnus, and Acer. Two forms of hedges, those sheared or trimmed and unsheared ones, were included.

The following is a list of the trees and shrubs planted in the sheared hedgerows and still growing:

Common name	Scientific name
Tatarian maple	Acer tataricum.
Box elder	Acer negundo.
Soft maple	Acer saccharinum.
Gray birch	Betula populifolia.
Siberian pea tree	Caragana arborescens.
———	Caragana spinosa.
Siberian dogwood	Cornus siberica.
———	Cotoneaster sp.
———	Crataegus pinnatifida.
Russian olive	Elaeagnus angustifolia.
Green ash	Fraxinus lanceolata.
Tatarian honeysuckle	Lonicera tatarica.
Ninebark	Opulaster opulifolius.
Goldleaf ninebark	Opulaster opulifolius aureus.
Mock orange	Philadelphus coronarius.
Chokecherry	Prunus virginiana.
Buckthorn	Rhamnus cathartica.
Golden currant	Ribes odoratum.
Sharpleaf willow	Salix acutifolia.
White willow	Salix alba.
Laurel-leaf willow	Salix pentandra.
Russian golden willow	Salix vitellina aurea.
Diamond willow	Salix mackenzieana.
Golden elder	Sambucus aurea.
Persian lilac	Syringa persica.
Himalayan lilac	Syringa emodi.
Japanese tree lilac	Syringa japonica.
Hungarian lilac	Syringa josikaea.
Late lilac	Syringa villosa.
Ural false spirea	Schizonotus sorbifolius.
American elm	Ulmus americana.
High bush cranberry	Viburnum opulus.
Snowball	Viburnum opulus sterile.

The following species were included in this test but proved to be not adapted for trimmed hedges:

Common name	Scientific name
June berry	Amelanchier alnifolia.
Chinese peach	Amygdalus davidiana.
Red-osier dogwood	Cornus stolonifera.
Cottonwood	Populus deltoides.
Snowberry	Symphoricarpos sp.

Common barberry (*Berberis vulgaris*) and the horticultural variety, purple-leaved barberry (*Berberis vulgaris atropurpurea*), were included in this test, but discarded because they are hosts for black stem rust of wheat and the planting of them is illegal in North Dakota.

The following species were planted, and are still growing, in untrimmed hedgerows:

Common name	Scientific name
Dwarf pink spirea	Spiraea bumalda var. Anthony Waterer.
Garland spirea	Spiraea arguta.
Billard spirea	Spiraea billardi.
Bumalda spirea	Spiraea bumalda.
Vanhoutte spirea	Spiraea vanhouttei.

Berberis thunbergi, *Rosa rugosa alba*, *Rosa rugosa rubra*, and *Spiraea callosa*, were also included in this test, but did not prove successful.

HARDY PERENNIALS

A large number of species and varieties of hardy perennials were tested in the period from 1913 to 1918, inclusive. Most of them died within two or three years after planting, but a small number did well, surviving the adverse conditions and blooming profusely with but little care. The most dependable and successful ones which survived three years or more were—

Common name	Scientific name
Milfoil	Achillea.
Golden marguerite	Anthemis.
Columbine	Aquilegia.
Oxeye daisy	Chrysanthemum uliginosum.
Pyrethrum	Chrysanthemum roseum.
Clematis	Clematis.
Lily of the valley	Convallaria.
Larkspur	Delphinium.
Bleeding heart	Dicentra.
Siberian meadowsweet	Filipendula palmata.
Blanket flower	Gaillardia.
Baby's-breath	Gypsophila.
Lemon lily	Hemerocallis.
German iris	Iris germanica.
Dwarf iris	Iris pumila.
Tiger lily	Lilium tigrinum.
Peony	Paeonia.
Iceland poppy	Papaver nudicaule.
Oriental poppy	Papaver orientale.
Phlox	Phlox.
Chinese bellflower	Platycodon.
Japanese astilbe	Astilbe japonica.

Other perennials tested but which were not successful were the following:

Common name	Scientific name	Common name	Scientific name
Hollyhock	Althaea.	Foxglove	Digitalis.
Alkanet	Anchusa.	French honeysuckle	Hedysarum.
New England aster	Aster.	Sunflower	Helianthus.
False indigo	Baptisia.	Heliopsis	Heliopsis.
English daisy	Bellis.	Japanese iris	Iris kaempferi.
Plume poppy	Bocconia.	Oriental iris	Iris sanguinea.
False-camomile	Boltonia.	Maltese Cross	Lychnis.
Hardy chrysanthemum.	Chrysanthemum indicum.	Lupine	Lupinus.
		Assorted lilies	Lilium.
Bellflower	Campanula.	Beardtongue	Pentstemon.
Tickseed	Coreopsis.	Ground pink	Phlox subulata.
Bugbane	Cimicifuga.	Coneflower	Rudbeckia.
Sweet William	Dianthus.		

ANNUAL FLOWERS

Included under annuals are a number of flowering plants, grown from seed either sown indoors and later transplanted to the open, or sown outdoors where grown. All were generally successful, blooming profusely during their season. The following annual flowers have been grown:

Common name	Scientific name	Common name	Scientific name
Ageratum	Ageratum.	Sweet pea	Lathyrus.
Alyssum	Alyssum.	Lobelia	Lobelia.
Snapdragon	Antirrhinum.	Stocks	Matthiola.
Asters	Aster.	Flowering tobacco	Nicotiana.
Pot marigold	Calendula.	Poppy	Papaver.
Cockscomb	Celosia.	Phlox	Phlox.
Dusty miller	Centaurea.	Petunia	Petunia.
Do	Cineraria.	Rose moss	Portulaca.
French marguerite	Chrysanthemum.	Mignonette	Reseda.
Cosmos	Cosmos.	Castor bean	Ricinus.
African daisy	Dimorphotheca.	Painted tongue	Salpiglossis.
Pink	Dianthus.	Mourning bride	Scabiosa.
California poppy	Eschscholtzia.	Marigold	Tagetes.
Annual blanket flower.	Gaillardia.	Nasturtium	Tropaeolum.
		Pansy	Viola.
Balsam	Impatiens.	Verbena	Verbena.
Everlasting	Helichrysum.	Zinnia	Zinnia.
Heliotrope	Heliotropium.		

HARDY AND TENDER BULBS

The tulip, narcissus, gladiolus, and dahlia were included in this class. Tulips have been tested quite extensively and have proved very successful and dependable, almost 100 per cent coming through the winter alive and blooming profusely during early summer. Both Holland bulbs and bulbs from the gardens of the Office of Foreign Seed and Plant Introduction at Bellingham, Wash., were tested, and all proved equally good. The most desirable class for this locality were the Darwin and Cottage varieties. These bloom so late in spring that they were seldom injured by frost. The narcissus varieties were planted only one year and were an absolute failure. The varieties of gladiolus were very successful, blooming well under ordinary field culture. Dahlia varieties tried out, bloomed so late that most of the flower crop was caught by early frost and the roots did not mature sufficiently to keep over winter in storage.

LANDSCAPE GARDENING

A systematic effort has been made to develop the grounds of the field station. In 1915 a considerable number of trees, shrubs, perennials, and semiformal flower beds were planted, for the double purpose of beautifying the station grounds and ascertaining the value of the various plant species for this section of the country. Numerous notes and observations have been made each year. The plant material that has been tested in this manner may be divided into the following groups: (1) Ornamental trees, both deciduous and coniferous; (2) ornamental shrubbery; (3) hardy perennials; and (4) bedding plants. Figure 4 gives a view of a section of the grounds showing the results of ornamental plantings.

ORNAMENTAL TREES

A number of each of the following kinds of deciduous trees were planted in groups of 6 to 10 or more, some in unit groups, and some in combination with other species:

Common name	Scientific name
Norway maple	Acer platanoides.
Ginnala maple	Acer ginnala.
Tatarian maple	Acer tataricum.
Soft or silver maple	Acer saccharinum.
Box elder	Acer negundo.
European white birch	Betula alba.
Gray birch	Betula populifolia.
Hackberry	Celtis occidentalis.
Russian olive	Elaeagnus angustifolia.
Green ash	Fraxinus lanceolata.
Black walnut	Juglans nigra.
Ironwood	Ostrya virginiana.
Silver poplar	Populus alba nivea.
Lombardy poplar	Populus nigra italica.
Northwest poplar	Populus sp.
Bur oak	Quercus macrocarpa.
Weeping willow (Niobe)	Salix babylonica.
Basswood	Tilia americana.
American elm	Ulmus americana.
Red elm	Ulmus thomasi.

FIG. 4.—Ornamental plantings at the Northern Great Plains Field Station

The Quercus, Celtis, Ostrya, Juglans, and some of the Ulmus species suffered severely from winter injury, and most of them died the following spring. The rest, with the exception of *Acer platanoides*, which died after the second year, have made splendid growth and apparently are doing well.

The following species or varieties were added in 1916 to the plantings, and all have made good growth:

Common name	Scientific name
Wild plum	Prunus americana.
Pin cherry	Prunus pennsylvanica.
Chokecherry	Prunus virginiana.
Northern cottonwood	Populus monilifera.
Carolina poplar	Populus sp.
Norway poplar	Populus sp.
Laurel willow	Salix pentandra.
Russian golden willow	Salix vitellina aurea.
Dwarf Asiatic elm	Ulmus pumila.

Conifers were also planted in groups of 6 to 75 trees, some as units and others in combinations. The unit groups have made better growth, and make a better appearance. The following list shows the species planted:

Common name	Scientific name
White spruce	Picea glauca.
Black Hills spruce	Picea glauca (var.).
Colorado blue spruce	Picea pungens.
Mugho pine	Pinus montana mughus.
Lodgepole pine	Pinus contorta latifolia.
Western yellow pine	Pinus ponderosa.
Scotch pine	Pinus sylvestris.

All of the species of Picea are doing well, and a few of the trees of *Pinus ponderosa* and *P. sylvestris* are growing, but only one *P. montana mughus* and no *P. contorta latifolia* survived.

ORNAMENTAL SHRUBBERY

This group was by far the largest in both numbers and species. The plantings on the whole were successful, making a good growth from the start, but considerable replanting was necessary during the first three years.

Notes and observations are made on the usefulness and ornamental value of the different species and varieties. The following have proved the hardiest and most successful as landscape subjects:

Common name	Scientific name
Ginnala maple	Acer ginnala.
Japanese barberry	Berberis thunbergi.
Siberian pea tree	Caragana arborescens.
Siberian dogwood	Cornus siberica.
Red-osier dogwood	Cornus stolonifera.
Cockspur-thorn	Crataegus crusgalli.
Silverberry	Elaeagnus argentea.
Tatarian honeysuckle	Lonicera tatarica.
Ninebark	Opulaster opulifolius.
Mock orange	Philadelphus grandiflorus.
Golden currant	Ribes odorratum.
Wild rose	Rosa blanda.
Japanese rose	Rosa rugosa.
Smooth sumac	Rhus hirta.
Buckthorn	Rhamnus cathartica.
Billard spirea	Spiraea billardi.
Bumalda spirea	Spiraea bumalda.
Garland spirea	Spiraea arguta.
———	Spiraea japonica fortunei.
Vanhoutte spirea	Spiraea vanhouttei.
Ural false spirea	Schizonotus sorbifolius.
Hungarian lilac	Syringa josikaea.
Persian lilac	Syringa persica.
Late lilac	Syringa villosa.
Common purple lilac	Syringa vulgaris.
Common white lilac	Syringa vulgaris alba.
Highbush cranberry	Viburnum opulus.
Snowball	Viburnum opulus sterile.

HARDY PERENNIALS

The only hardy perennial that has proved entirely dependable and successful is the peony. A large bed planted to German iris winterkilled the first year, as did also a number of perennials grown from seed planted in a long border. The failure was probably due as much to drought as to winterkilling, however, and this group of landscape-gardening plants is to be tested more thoroughly.

BEDDING PLANTS

Several beds of the more favored type of flowers have been grown on the station grounds. Cannas and geraniums have made up most of the plant material used, with a few other species included. All beds were very successful and repaid the extra care involved in this phase of landscape work.

OLERICULTURE

In the average year on the northern Great Plains success with vegetables appears to be more of a certainty than is the case with fruit. Vegetable growing will hardly become of commercial importance, but the farmer and home gardener should be able to grow adequate supplies for their own needs. The absence of farm gardens in this region and the large quantities of fresh and canned vegetables annually shipped into the small towns would seem to indicate that vegetable growing, like fruit growing, must be practiced along lines different from those followed in more favored sections.

Experimental work with vegetables at this station has been directed along three lines: (1) Varietal tests, to determine the varieties of the different classes of vegetables best adapted to conditions; (2) vegetable breeding, to improve the quality, production, or adaptation of the most promising varieties; and (3) a 1-acre rotation garden, to determine the possibilities of garden production and the cultural methods best suited to the farm garden in this section.

Potato varietal and cultural tests and potato-breeding investigations have been conducted as a part of the olericulture work.

VARIETAL TESTS

Tests of a few varieties of the common vegetables were begun in 1913 and later increased to include more classes and varieties and various strains of the same variety. The usual custom of starting long-season crops in hotbeds and later transferring them to the field and planting others in the open with a garden drill was followed. Seasonal notes on quality, yield, and other characters were made each year and the yields determined. Varietal tests of vegetables were discontinued as a separate line of work after 1918, and attention was concentrated on the improvement of certain ones and on working out methods of farm-garden management and the possibilities of production in the 1-acre farm garden.

The details and results of the varietal tests will not be presented here. Nothing will be attempted in this report except to show the scope of the work and the general character of the results with each of the garden vegetables.

Asparagus.—Two plantings were made of varieties of asparagus raised from seed. There was only slight winterkilling, and fairly satisfactory yields were obtained.

Beans.—Eighteen varieties were tested as shell beans, and 33 varieties as string or snap beans. Both proved fairly reliable crops, free from disease and with but few insect enemies. A number of varieties of Lima beans were tested, but none reached an edible stage before frost.

Beets.—Thirteen varieties were tested as early or pickling beets, and 10 as late or winter beets. This vegetable, like most of the root crops, is successfully grown here. Results with early beets were particularly good. There was always moisture enough to carry them to the early stage of growth at which they are harvested and to produce roots of good quality.

Cabbage.—Early cabbage was one of the most reliable garden vegetables tested. Of the 23 varieties of early cabbage grown in these experiments, Early Jersey Wakefield and Copenhagen Market were by far the most successful and dependable. Late cabbage was not as successful or dependable as early. The round-headed or flat round were the most successful types or forms, and the red and Savoy varieties were nearly—or entirely—failures.

Carrots.—Early carrots were not, on the whole, successful. The varieties under trial were neither especially early nor as good in quality as the late varieties. Late carrots were a successful and dependable crop every year.

Cauliflower.—Cauliflower was tested as an early and as a late vegetable. The distinction between the two classes was either that of variety or cultural method, or both. Early cauliflower was a dependable vegetable of fine quality, but very poor results were obtained with late cauliflower. The varieties that uniformly gave the best results as an early crop were Early Dwarf Erfurt, Burpee's Best Early, and Early Snowball.

Celery.—Very satisfactory results were obtained with celery both as an early and a late crop. Varieties that proved generally reliable and of the easiest culture were Golden Self-Blanching, Silver Self-Blanching, Giant Pascal, and Winter Queen.

Cucumbers.—Cucumbers were generally successful and free from disease. White Spine was the most satisfactory variety as a slicing cucumber, and Chicago Pickling was the best in shape and yield of the pickling cucumbers.

Eggplant.—Fairly good results were obtained with this vegetable, but its culture is exacting. It must not be stunted in transplanting, and unless weather conditions are especially favorable at the time of setting in the field pot-grown plants are essential to success. The best varieties tested were Early Dwarf Purple, Black Pekin, and Black Beauty.

Lettuce.—Leaf lettuce gave very good results from both transplants and field seeding. Head lettuce was not a dependable crop under ordinary field conditions, but a large percentage of good heads was obtained from April-sown transplants. Black-seeded Simpson, Prize Head, and Grand Rapids, were all equally good as leaf lettuce; and Wayahead, May King, Salamander, and Hanson, were the best and most dependable varieties of head lettuce.

Muskmelon.—A considerable number of varieties were tested, but results generally were very poor, the season not being long enough for them to mature. The best results were obtained from the earliest varieties.

Onion.—This vegetable gave fair to good results every year, under ordinary field culture. The Southport Globe varieties, on the whole, seemed the most desirable as to yield and market value. Australian Brown, being one of the best keepers, is very valuable for home use.

Parsnip.—Six named varieties were tested and all produced good yields. Improved Guernsey was considered the most desirable and proved a very dependable variety.

Peas.—No actual crop failure of early peas was experienced in any year, but yields generally were rather small. Dwarf varieties, on account of economy of space and ease of culture, were found to be the most desirable. Late or main-season peas were rather light producers, and the crop had a tendency to spoil quickly in hot weather, but all varieties yielded a crop. Varieties of the Telephone type, such as Alderman, Prince Edward, and Improved Telephone, gave the best results.

Pepper.—Several varieties were tested and grown with success. Potted plants are preferable, as they are more certain to produce a crop, but fair results were obtained with transplants. The varieties that succeeded best were Ruby King, Baby Bell, and Neapolitan, of the large-podded, mild class; and Chile, of the small-podded, pungent class.

Pop corn.—Pop corn was not very successful. The very early varieties were of inferior quality. White Rice seemed by far the best variety, but for this area it needs selection and breeding for earliness.

Pumpkin.—Late varieties of pumpkins were almost total failures, but early varieties gave fair to good yields. Small Sugar and Connecticut Field were the best of these.

Radish.—Of early radishes, 36 varieties were tested. The class as a whole was very satisfactory. Varieties of the Sparkler, or turnip-shaped type, and the Icicle variety, of the long-rooted type, were the best. The oblong or olive-shaped varieties were not so good. Summer radishes were not as generally satisfactory as the early radishes, but gave fair results. Varieties of the long-rooted type appeared to do better than the others. Five varieties of winter radish were

tested. All gave very good yields except Rose China, which had too great a tendency to run to seed. Half Long Black Spanish yielded uniformly well.

Rhubarb.—Rhubarb yielded enormously every year, without attention other than keeping it clean.

Rutabaga.—Rutabagas were very successful in years of sufficient rainfall, but in the drier years the quality was so poor that the crop was practically a failure as a table vegetable. In both quality and yield Winter King, Golden Heart, and Long Island Improved were the best varieties tested.

Salsify.—This vegetable gave fair results. Its culture was easy, but it showed a tendency to form fibrous roots instead of a taproot. This probably was due to insufficient moisture in ordinary years. The largest and best variety tested was Mammoth Sandwich Island.

Spinach.—Nearly all of the 12 varieties tested produced good crops of excellent quality every year. The Savoy, or crumpled-leaved, varieties were slightly the higher yielding. The best varieties were Norfolk Savoy-Leaved, Victoria, and Long Season. New Zealand was very good in the fall.

Squash.—Scallops or cymlings, crooknecks, and vegetable marrows were tested as summer squash. All produced good yields, but the vegetable-marrow type seemed preferable. The best varieties of summer squash were Cocozelle, Bush Vegetable Marrow, and Long Island White Bush Scallop. Most of the varieties of winter squash produced a crop somewhat influenced as to quality and quantity by the early or late appearance of frost. The Early Prolific Marrow was more reliable than the Hubbard type, of which Golden Hubbard was the best in yield but not in quality.

Sweet corn.—From 7 to 24 varieties were grown each year. A crop was made every year of all varieties except Country Gentleman, which is entirely too late for this section and which produced only a few ears in only two of the five years that it was planted. The most dependable varieties and those of the best quality were Golden Bantam, Early White Mexican, Red Cob Cory, White Cob Cory, Peep O'Day, and Black Mexican.

Swiss chard.—Swiss chard, or spinach beet, was one of the most reliable and satisfactory vegetables grown, producing abundantly from early in July until frost. Lucullus, a variety with thick, crumpled leaves, was the best of the six varieties tested.

Tomatoes.—This is one of the most valuable garden crops in this section and was a success every year except in 1915, when all the tomatoes in the varietal test were destroyed in midsummer by disease. Ordinary field culture proved of little value, as the crop matured so late that the largest part of it was destroyed by frost. To mature the crop it was found necessary to stake and prune to a single stem. It is also necessary to start the plants in a hotbed, transplant to a coldframe or into pots, and set them in the field around May 25 to June 2. Some of the best varieties tested were Sunnybrook Earliana, Bonny Best, John Baer, Detroit or Trucker's Favorite, Red Ponderosa, and Golden Ponderosa.

Turnips.—All varieties yielded well, the principal difference being in quality. Some were so strongly flavored as to be of no value as a vegetable, but a few were palatable every year. The best of the 17 varieties tested were Snowball, Golden Ball, Model, and Cowhorn.

Watermelon.—Twenty-four varieties of watermelons were tested, but only the earliest ones succeeded. Unless there was good rain in July the plants blossomed and set fruit too late to mature before frost. The most reliable varieties were Fordhook Early, Cole's Early, Kleckley Sweets, and Sweet Siberian.

Minor vegetables and herbs.—During the years that varietal testing was conducted a number of vegetables and herbs that are less known or not commonly grown in this area were tried. The following are recorded as good in both quality and production: Anise, citron, dill, endive, groundcherry, horseradish, kohlrabi, leek, mustard, parsley, sage, summer savory, and thyme. Broccoli and Brussels sprouts were too late to produce a good edible product even in an exceptionally long season. Caraway was grown only one year and gave poor results, but should succeed here. Celeriac produced but few edible roots even when handled the same as celery. Two varieties of chicory were grown one year with fair results. Kale made good growth, but did not survive heavy frosts in the fall and is, on the whole, of little promise for this section. Lentils matured but few pods. Okra produced a fair crop each year under ordinary field culture. The season is not long enough for sweet potatoes. Only one variety produced a few edible roots. Turnip-rooted parsley, from both field sowing and transplants, succeeded fairly well.

VEGETABLE BREEDING

More or less breeding has been done with vegetables to adapt available varieties to conditions of the northern Great Plains. Most of the work has been devoted to tomatoes. Attention has been concentrated on this vegetable because of its great potential importance for the farm and home gardens of this area. The object is to get earlier tomatoes and at the same time improve or at least maintain prolificacy and the quality, shape, size, and smoothness of the fruit.

Systematic attempts to improve the tomato for this section began with the making of selections from the Sunnybrook strain of Earliana in 1915. Plants were grown from these selections in 1916 and further selections made. Selections were again made from the progeny in 1917 and the work increased by individual plant selections from eight other varieties in the varietal tests. Seed from these selections was planted in the greenhouse, and cross-fertilization was effected during the winter. Both these crosses and the selections made in 1917 were grown in the field in 1918, and 94 individual plant selections were made. The tomato breeding was temporarily suspended in 1919, but was resumed in 1920 by planting seed from the selections made in 1918 from the crosses and from a few Earliana and Golden Ponderosa plants. About 4,200 plants from these selections were set in the field. In making selections from these, a number of strains were discarded. In 1921 and 1922 the work was continued on about the same scale. Marked progress is being made, particularly in quality, yield, and disease resistance. Unfavorable seasons have interfered somewhat with selection for extreme earliness.

The most promising strains from which most selections were made in 1922 are Earliana, Golden Ponderosa, Earliana × Scarlet Ponderosa, Scarlet Ponderosa × Earliana, Golden Ponderosa × Burbank, and Burbank × Golden Queen.

DEMONSTRATION GARDEN

In the spring of 1920 a garden, practically an acre in size, was started to determine the possibilities of farm-garden production. The patch is 160 by 272 feet. It is divided into four plats, each 68 by 160 feet. The vegetables are grouped into four main classes—root crops, legumes, vines and potatoes, and leaf crops—and, as nearly as possible, each class occupies one of the four plats of ground. A rotation is practiced, so the legumes follow the roots, the vines and potatoes follow the legumes, the leaf crops follow the vines and potatoes and are themselves followed by the root crops. One of the four plats is manured each fall, the manure being applied in advance of the leaf crops.

The rows are 160 feet long, and (except the onion rows, which are 18 inches apart) 3 feet, 6 feet, or 9 feet apart. The wider spacings are for vines. This arrangement allows most of the cultivation to be done with horses. The allotment of space to the different vegetables was based on estimates of production and the requirements of a family of five, with a surplus for disposal. The plan of the garden is shown in Figure 5.

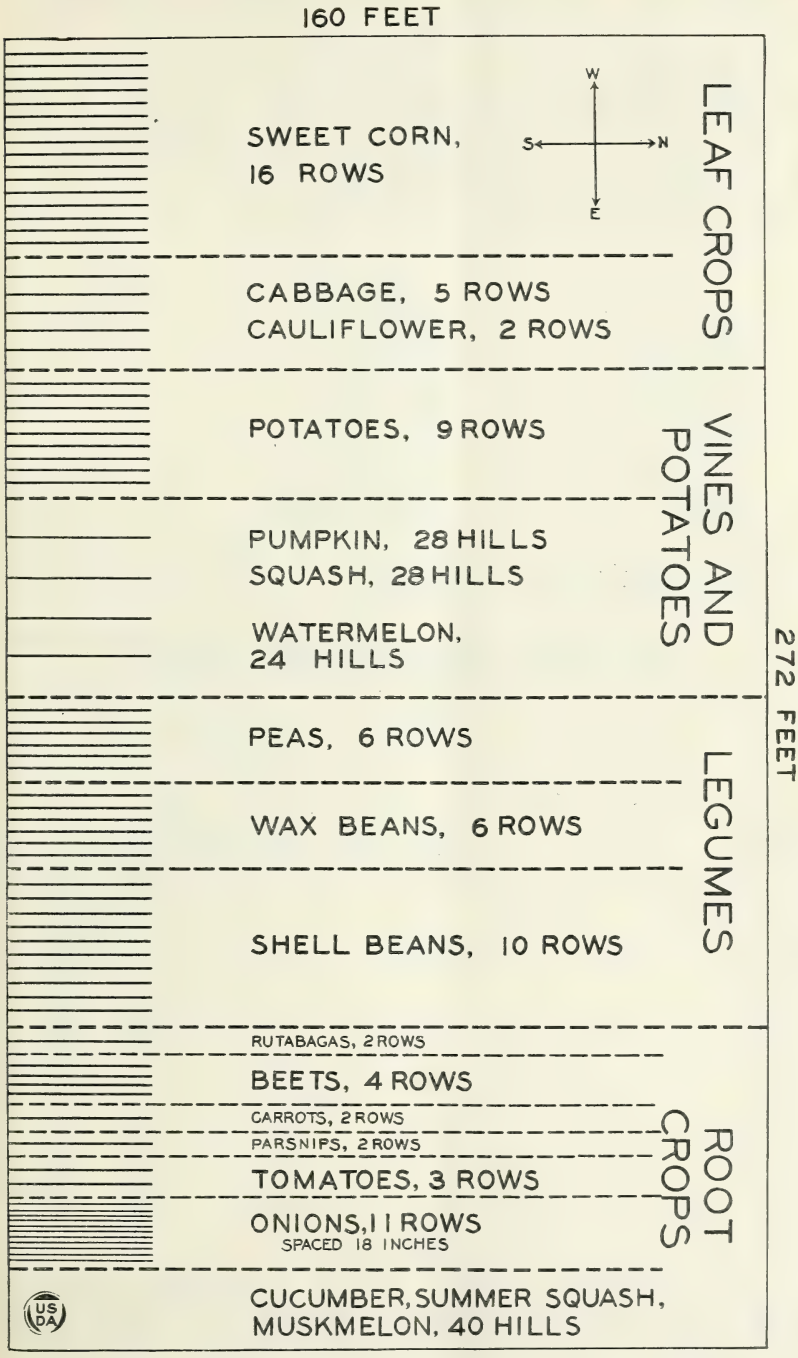

FIG. 5.—Plan of the 1-acre rotation garden at the Northern Great Plains Field Station

The following vegetables and varieties are used in this garden:

Vegetables	Varieties
Bean, shell	Pilot Navy.
Bean, wax	Saddleback wax, Kidney wax.
Beet, pickling	Eclipse.
Beet, winter	Detroit Dark Red.
Cabbage, early	Jersey Wakefield, Copenhagen Market.
Cabbage, late	Copenhagen Market, Danish Ballhead.
Cauliflower, early	Burpees Best Early.
Cauliflower, late	Snowball.
Carrot	Chantenay.
Cucumber	Fordhook Famous.
Melon:	
Muskmelon	Emerald Gem.
Watermelon	Fordhook Early.
Onion	Southport Globe, Australian Brown.
Parsnip	Guernsey.
Peas, early	Alaska.
Peas, main season	Notts Excelsior.
Potatoes	Early Ohio.
Pumpkin	Small Sugar.
Rutabaga	Golden Neckless.
Squash, summer	Cocozelle.
Squash, winter	Golden Hubbard.
Sweet corn	Golden Bantam.
Tomatoes	Sunnybrook Earliana.

The yields from this acre of garden for the three years 1920–1922, are given in Table 14.

TABLE 14.—*Yields of vegetables from the 1-acre rotation garden at the Northern Great Plains Field Station for 1920, 1921, and 1922*

Variety	Unit of measurement	Year		
		1920	1921	1922
Bean, shell	Pounds	107	18	120
Bean, wax	Quarts	190	42	523
Beet, pickling	Pounds	150	156	268
Beet, winter	do	218	207	558
Cabbage, early	do	485	360	1,087
Cabbage, late	do	195	530	1,062
Cauliflower, early	do	46	28	135
Cauliflower, late	do	8	0	81
Carrot	do	145	317	895
Cucumber	do	58	75	151
Melon:				
Muskmelon	do	31	45	49
Watermelon	do	368	0	600
Onion	do	547	388	897
Parsnip	do	67	97	335
Peas, early	Quarts	7	24	45
Peas, main crop	do	22	25	115
Potatoes	Pounds	800	(1)	1,125
Pumpkin	do	672	652	651
Squash, summer	Fruits	28	16	40
Squash, winter	Pounds	1,485	0	560
Rutabaga	do	135	75	300
Sweet corn	Ears	242	500	1,400
Tomato	Pounds	458	354	954

[1] Record lost.

POTATOES

Potatoes have been a fairly sure crop at the station. Although yields have varied considerably from year to year, there has not been a complete failure since the work was started in 1913.

Three lines of experimentation with potatoes have been followed: Varietal tests, spacing experiments, and selection.

More than 30 varieties of potatoes have been tested, some but a single year and others for varying lengths of time up to 10 years. Uninterrupted yields were obtained from three varieties for the 10 years, 1913–1922, inclusive. During this period Green Mountain averaged 185 bushels, Irish Cobbler 163 bushels, and Rural New Yorker 144 bushels, per acre. Green Mountain was the highest yielding variety in the tests in 1913, 1914, and 1921. Of those varieties that have outyielded Green Mountain more than once, Pink Eye had the higher yield three times in the nine years that both were grown; Irish Cobbler and Rural New Yorker each exceeded it twice in 10 years; Early Ohio exceeded it once in 9 years; and Early Acme and Blue Victor twice each in 8 years.

Various tests have been made in which the same variety was grown from seed from different sources, and wide differences have been noted in the yields. The results show a tendency of home-grown seed to run out or degenerate. This factor greatly interferes with the accuracy and interpretation of variety trials. The problem of keeping potatoes vigorous, and free from disease and degenerate types, appears to be one of great importance here.

Experiments to determine the best distance to space hills of potatoes in the row have been conducted each year except 1915. From three to nine varieties have been under trial each year at different spacings, ranging from 14 to 30 inches. The average yields favor the closer spacing, but the higher yield from the closer spacing was sometimes obtained at the expense of quality and size. On the whole, the 20-inch spacing has been the most desirable.

Considerable selection work with potatoes has been done, starting with the fall of 1914. The method first employed was to select superior hills of all varieties in the field at digging time and test the selections in bulk in comparison with the parent stocks.

Starting with 1918 the selections were made on an individual-hill basis, with the number of varieties reduced to four, viz: Early Ohio, Irish Cobbler, Rural New Yorker, and Pink Eye. The best 10 hills of each of these varieties were selected and the progeny of each hill kept separate.

Starting with 1921 the tuber-unit method was used; that is, the progeny of each tuber was kept separate and selections were made of the best tuber units. This latter method is still being used with several standard varieties of potatoes.

Results to the present time from the selections have been largely negative, in that no higher yielding strains have been isolated.

AGRONOMIC INVESTIGATIONS [9]

ROTATION AND TILLAGE EXPERIMENTS

The rotation and tillage experiments occupy two fields, known as the main field and the south field. The soil of the main field is a comparatively light sandy loam containing about 10 per cent of clay in the surface foot. The soil of the south field is much heavier, containing about 25 per cent of clay in the surface foot. This field slopes to some extent and is subject to run-off, both on it and from

[9] By J. T. Sarvis, Associate Agronomist, and J. C. Thysell, Assistant Agronomist, Office of Dry-Land Agriculture Investigations.

it, which interferes with the uniformity of the yields. The main field contains 225 tenth-acre plats and the south field 60 tenth-acre plats. The plats are 132 feet long and 33 feet wide. They are separated along the sides by 4-foot alleys, and along the ends by 20-foot roadways and are divided into blocks of 12 plats each by 20-foot roadways. The alleys and roads are cultivated and kept free of vegetation.

The methods of cultural treatment under trial are spring plowing, fall plowing, disked corn ground, summer fallowing, subsoiling, listing, and green manuring. All plowing except for special treatments is done to a depth of 6 inches. Corn ground to be sown to spring grain is disked once with a double cutaway disk shortly before seeding. Summer fallow is plowed the first week in June and kept free from weeds the rest of the season by cultivation. All subsoiled plats are fall-plowed to a depth of 6 inches, and the subsoiler is run in the bottom of each furrow to a further depth of 8 inches, loosening the soil to a total depth of 14 inches. Subsoiling is done for two years in succession and then omitted for two years. Listing is done to a depth of 6 to 8 inches in the fall for all small-grain crops that receive this treatment. Winter rye, peas, and sweet clover are grown and plowed under for green manure. This treatment is a modification of summer fallow, differing from it in the kind and quantity of the green matter that is turned under and the time of plowing. The green-manure plats are plowed from four to six weeks later than summer fallow.

Table 15 shows the crops that are regularly grown in the rotations, the varieties used, the rate of seeding, and the number of plats of each crop seeded annually. The varieties used are those that are considered well adapted to the locality. The same variety of a given crop is seeded in all plats.

TABLE 15.—*Crops, varieties, seeding rate, and number of plats seeded annually in the crop rotation and cultivation experiments at the Northern Great Plains Field Station*

Crop	Variety	Seed per acre	Number of plats seeded annually
Spring wheat	Kubanka	4 pecks	67
Winter wheat	Turkey or Kharkof	4 pecks	5
Oats	Sixty-Day	6 pecks	64
Barley	Hannchen	5 pecks	22
Corn	Northwestern Dent		64
Flax	North Dakota Wilt Resistant	20 pounds	12
Potatoes	Early Ohio	10 bushels	2
Alfalfa	Grimm	6 to 8 pounds	1
Bromegrass	Bromus inermis	12 pounds	1
Sweet clover	White	10 pounds	2
Winter rye	Common	50 pounds	2
Peas	Canadian Field	2 bushels	2
Sorgo	Dakota Amber	8 pounds	1

Spring-plowed and fall-plowed plats that are seeded to spring small grains are harrowed twice in the spring. Fall-plowed plats are left rough over winter. Spring-plowed plats to be seeded to corn are harrowed twice before seeding. Fall plowing for corn is harrowed once at the time the plats for small grain are harrowed and again when the spring-plowed plats for corn are harrowed.

Summer-fallowed plats to be seeded to small grain are usually harrowed twice before seeding. Sometimes the spring-tooth harrow or the disk harrow is used instead of the spike-tooth harrow. The disk harrow is not used extensively, since it increases the work necessary to prepare a seed bed. It also pulverizes the soil to such an extent that blowing is likely to occur on the lighter soils.

In the treatment of summer fallow the practice is to harrow the plats once immediately or soon after plowing. This operation levels the soil and leaves it in such condition that the implements used later do their work to the best advantage. The fallow plats have not been disked since 1917, or after the soil was free from sod. A knife weeder and spring-tooth harrow have been used to keep the plats free from weeds. In 1922 a duck-foot cultivator was used to advantage. Fallow should be cultivated to keep it free from weeds and to leave it in a receptive condition for rains, and rough to avoid soil blowing. Figure 6 shows summer fallow after cultivation with a duck-foot cultivator.

FIG. 6.—Summer-fallow plats after cultivation with a duck-foot cultivator at the Northern Great Plains Field Station, July 14, 1922

In the main field spring wheat, winter wheat, barley, oats, flax, and corn are grown under systems of continuous cropping. Six plats are required for each crop. On two of the six plats crops and summer fallow alternate. In the south field spring wheat, barley, oats, and corn are grown in duplicate under the system of continuous cropping. Rotations 5 and 8, in the south field, are also in duplicate. Plat A of the continuous-cropping plats of spring-sown crops is shallow spring plowed and harrowed once before seeding; plat B is fall plowed to a depth of 6 inches, left rough over winter, and harrowed twice before seeding; plats C and D are alternately summer fallowed and cropped, one being in crop each year; plat E is fall plowed and subsoiled, left rough over winter, and harrowed twice before seeding; and plat F is listed in the fall and worked down before seeding, except for corn, for which it is spring listed.

Rotations 1 to 9, inclusive, are repeated three times in the main field. Each of these rotations appears in series I, series II, and series III, and each block of 27 plats across the three series also contains each of the nine rotations. The results from these rotations show that if the yields of any one of the combinations were used, the conclusions would not be changed from those derived from any other set.

The land upon which the rotations are located was broken during May and June, 1913, and backset in the fall. The yields of all crops were high in 1914 because of the very favorable season. The 1914 yields are not included in any of the tables presented, because all crops were on land given uniform treatment.

The yields following summer fallow in 1915 are not entirely comparable with those following other tillage methods or those of other years, because the plats were not only fallow in 1914 but were semi-fallow in 1913.

SPRING WHEAT

The yields of spring wheat from the main and south fields for the years, 1915 to 1922, inclusive, are presented in Table 16. The wheat yields for the 3-year period, 1919–1921, inclusive, were low, because of the dry seasons. While 1917 and 1918 were also dry, the yields under most of the cultural methods were not exceedingly low.

In a comparison of wheat yields following different cultural treatments, disked potato ground has produced a yield equal to that on summer fallow. Disked potato ground is an excellent preparation for wheat. The one plat receiving this preparation is in a 4-year rotation which contains manured summer fallow in addition to the potatoes. That the high yield following potatoes is not due to the manure in the rotation is indicated by the results from a similar rotation containing manured fallow, in which the potatoes are replaced by corn. The yield of wheat in this rotation is not above the average on disked corn ground in rotations that receive no manure.

In discussing the yields from summer-fallowed land, it should not be forgotten that twice as much land is required to produce the yields on fallow as on land continuously cropped. As much land is needed for a crop of wheat on fallow as is required to produce a crop of wheat and one of corn or potatoes. If the land is to produce equal values, the value of the crop after summer fallow should equal the combined values of the crop of wheat and the crop of corn or potatoes that take the place of the fallow. In the case of continuous cropping, the value of the crop on summer fallow should equal two continuous-cropping crops.

The yields in Table 16 show the following points: Plowing corn ground, instead of disking it, for wheat has not increased the yield enough to pay for the labor of plowing. Spring plowing for wheat has been slightly better than fall plowing. Land manured before plowing for summer fallow has produced higher yields than unmanured land. Crops turned under for green manure have not increased the yields over summer fallow. The yields indicate that the green manure, as compared with fallow, has a depressing effect on yields, but the reason for the difference may be found in the time of plowing under the green manure and the time of plowing for fallow. The subsoiled plat, which is directly comparable to the fall-plowed plat after

wheat has produced a yield equal to the fall-plowed plat, but subsoiling requires more labor and expense than fall plowing. The listed plat has produced yields about the same as those given fall plowing and subsoiling. The method, however, is not as expensive as subsoiling.

TABLE 16.—*Yields of spring wheat in two fields at the Northern Great Plains Field Station following different cultural treatments and various crops for the 8-year period, 1915–1922, inclusive*

Field, treatment, and previous crop	Number of plats averaged	Yields per acre (bushels)								
		1915	1916	1917	1918	1919	1920	1921	1922	Average
MAIN FIELD										
Disked:										
Corn	16	34.5	18.4	14.3	14.8	12.1	7.3	0.8	23.7	15.7
Potatoes	1	39.7	22.5	21.5	20.5	14.8	6.5	1.8	27.0	19.3
Spring plowed:										
Corn	3	35.2	20.7	15.0	20.5	11.5	7.6	.9	22.6	16.8
Oats	3	27.2	22.9	14.5	17.9	11.6	5.1	3.3	27.1	16.2
Spring wheat	1	30.5	19.2	15.3	12.7	7.5	1.5	1.8	19.5	13.5
Flax	1	28.8	19.5	12.8	13.2	6.2	4.2	0	20.2	13.1
Fall plowed:										
Corn	3	33.0	22.6	10.7	15.3	13.7	3.7	0	19.0	14.8
Oats	7	33.5	23.5	13.8	10.4	9.4	3.5	0	19.1	14.2
Spring wheat	1	32.1	18.5	14.8	15.3	5.3	1.0	0	12.2	12.4
Summer fallowed:										
Unmanured	10	44.1	22.7	16.0	23.0	13.1	8.1	3.4	24.0	19.3
Manured	2	41.6	29.7	24.1	26.0	14.3	14.4	4.3	30.4	23.1
Green manured:										
Winter rye	1	29.6	24.3	21.8	18.8	10.0	10.8	1.0	17.7	16.8
Peas	1	38.1	27.5	22.7	25.5	11.0	0	0	10.7	16.9
Sweet clover	1	32.4	28.2	17.8	12.2	13.7	4.7	1.5	12.5	15.4
Subsoiled:										
Spring wheat	1	31.7	18.8	15.3	7.7	7.5	0	0	15.2	12.0
Listed:										
Spring wheat	1	32.6	18.7	11.3	14.7	5.4	3.8	0	17.2	13.0
Average of all 53 plats		35.7	21.5	15.2	16.9	11.5	6.3	1.4	22.1	16.3
SOUTH FIELD										
Spring plowed:										
Spring wheat	2	28.2	15.4	8.9	0	7.2	0	0	19.6	9.9
Fall plowed:										
Spring wheat	2	30.9	17.4	6.1	0	5.8	0	0	10.9	8.9
Oats	2	32.7	19.9	8.5	0	8.6	1.1	0	17.2	11.0
Summer fallowed	4	42.7	15.5	13.7	6.2	14.3	8.4	0	17.6	14.8
Subsoiled:										
Spring wheat	2	25.2	15.8	6.7	0	5.7	0	0	20.4	9.2
Listed:										
Spring wheat	2	27.3	17.8	6.9	0	7.0	3.3	0	19.1	10.2
Average of all 14 plats		32.8	16.7	9.2	1.8	9.0	3.0	0	17.5	11.3

The yields of wheat in the south field are lower than in the main field. The difference is partly due to the heavier soil in the south field, and partly to greater run-off from it. Plats in the main field that are strictly comparable with those in the south field show an average yield of 4.3 bushels more per acre. The average yield from fallow in the south field is 4.9 bushels per acre less than from similar plats in the main field.

Judged by the results of the experiments to date, the most profitable method of raising spring wheat in this section is to use disked corn ground. This would be in a system of livestock and grain farming. However, in the case of wheat growing alone, if the farmer does not want to grow corn, or if corn will not grow successfully, summer fallow and spring wheat would be a better method to follow.

Spring wheat is an important crop in this section, and no doubt will continue for some time to occupy the most prominent place in the cropping system.

WINTER WHEAT

Winter wheat has been sown on five continuously cropped plats for nine seasons. Plat A is plowed just before seeding, plat B is early fall plowed, plats C and D are alternately fallowed and cropped, plat E is early fall plowed and subsoiled, and plat F is listed early and worked down before seeding. Winter wheat has not survived the winter during any year on any of these plats, and they have been resown to spring wheat. It has lived when sown in the bottom of lister furrows, but the yield was not enough to be profitable. Winter wheat has been sown in standing cornstalks and standing sorgo stalks, but it did not live in either place, although put in under the best of conditions. Winter wheat has been grown successfully in limited areas in this section by drilling it into grain stubble. This seems to be the most promising method for anyone who wants to try this crop.

TABLE 17.—*Yields of oats in two fields at the Northern Great Plains Field Station following different cultural treatments and various crops for the 8-year period, 1915–1922, inclusive*

Field, treatment, and previous crop	Number of plats averaged	Yields per acre (bushels)								
		1915	1916	1917	1918	1919	1920	1921	1922	Average
MAIN FIELD										
Disked:										
Corn	9	71.9	45.7	27.2	27.5	24.6	15.5	6.3	56.4	34.4
Potatoes	1	68.3	62.5	43.1	33.1	30.0	23.8	9.7	67.8	42.3
Sorgo	1	53.1	50.9	26.9	25.0	25.6	20.0	7.2	55.6	33.0
Spring plowed:										
Corn	6	72.7	52.0	28.2	33.7	24.9	17.5	10.0	57.8	37.1
Spring wheat	4	60.3	53.4	26.9	30.3	24.2	8.5	12.8	63.9	35.0
Flax	1	45.3	45.0	23.4	27.5	15.3	17.5	9.4	50.6	29.3
Oats	1	45.8	44.4	28.1	29.7	15.9	1.3	11.3	47.5	28.0
Fall plowed:										
Spring wheat	12	68.5	55.9	24.8	19.9	21.8	6.1	0	42.2	29.9
Barley	3	66.0	58.5	26.6	18.5	23.4	7.4	0	38.5	29.9
Oats	1	59.8	57.5	23.1	25.0	10.3	.9	0	29.1	25.7
Summer fallowed:										
Unmanured	5	103.5	66.0	39.1	44.9	28.4	24.9	13.0	74.3	49.3
Manured	2	100.6	66.9	45.8	51.1	31.9	29.9	8.9	77.2	51.5
Green manured:										
Winter rye	1	63.6	58.8	41.2	24.7	19.4	14.4	6.6	35.0	33.0
Peas	1	85.9	65.9	35.3	29.1	21.3	5.3	6.6	25.9	34.4
Sweet clover	1	56.1	79.7	33.8	22.8	22.5	13.1	7.8	27.5	32.9
Sod:										
Brome grass	1	57.2	39.4	13.4	24.4	20.0	6.9	8.8	(1)	[2] 24.3
Alfalfa	1	70.0	68.8	18.4	18.8	19.1	9.4	0	(1)	[2] 29.2
Subsoiled: Oats	1	57.5	57.2	19.1	18.4	14.1	1.6	0	38.1	25.8
Listed: Oats	1	49.8	54.7	25.0	27.5	13.4	9.7	6.6	44.4	28.9
Average of all 53 plats [3]		71.2	55.3	28.6	28.3	23.2	12.9	6.1	52.5	34.8
SOUTH FIELD										
Spring plowed: Oats	2	62.9	56.3	17.4	0	24.6	1.3	4.1	51.9	27.3
Fall plowed:										
Oats	2	78.0	57.8	21.3	0	18.8	3.3	0	46.9	28.3
Spring wheat	2	75.3	51.1	21.3	0	21.4	4.1	3.8	45.7	27.8
Summer fallowed	4	123.8	63.1	31.9	27.5	32.6	26.7	7.8	51.1	45.6
Subsoiled: Oats	2	68.8	59.7	23.0	0	23.0	1.7	0	51.7	28.5
Listed: Oats	2	78.6	56.6	21.7	0	25.0	12.0	1.7	55.5	31.4
Average of all 14 plats		87.3	58.3	24.0	7.9	25.4	10.8	3.6	50.5	33.5

[1] Discontinued in 1922. [2] 7-year average. [3] 51 plats in 1922.

OATS

Oats have been grown under the same general cultural conditions as spring wheat and have shown much the same response. The yields of oats in both fields for the eight years from 1915 to 1922, inclusive, are given in Table 17. Fall plowing for oats has yielded less than either spring plowing or disked corn ground. The yield on summer fallow has been higher than that under any other method, but, as was shown in considering the results with spring wheat, summer fallow requires twice the acreage of other methods. The yields on green manure have been about equal to those on disked corn ground and less than those on fallow. The difference between the results on fallow and on green manure are largely due to differences in the time of plowing. Oats have been grown on alfalfa sod and on bromegrass sod, but the yields have been uniformly low on both. In 1922 flax was substituted for the oats on sod.

Under most methods, the yield on the heavier soil of the south field has been only slightly less than that on the lighter soil of the main field. In the case of the listed and subsoiled plats the yield has been slightly larger than that in the main field. This increase has been due to run-off, which benefited these plats in the south field.

Oats are a valuable feed crop for this section. They fit well into a rotation with corn and wheat. In such a rotation, the oats would be best placed on spring plowing after spring wheat. The crop is not valuable enough to demand such an expensive method as summer fallow. Both corn and potato ground furnish a good preparation for oats, but they are usually sown to spring wheat for which they are equally good.

BARLEY

Barley is another grain grown for feed. In bushels per acre the yield of barley is less than that of oats, but in pounds per acre the yields of the two are very close. Barley fits well into a rotation with corn and oats or corn and wheat. The yields of barley in the main and south fields for the eight years, 1915–1922, inclusive, are shown in Table 18.

In the rotations barley is grown on disked corn ground and on disked flax stubble. The yield on disked flax stubble has been only slightly more than half the yield on disked corn ground. The yield following spring plowing was less than that following fall plowing in the main field, but in the south field the yield following spring plowing was slightly higher than that following fall plowing. The fall-plowed plat in the main field has received run-off which increased the yield. The yield on summer fallow averaged for the eight years 6.6 bushels per acre more than on corn ground. As in the case of other crops, twice the number of plats is required to grow barley on fallow as on continuously cropped plats. The same number of plats was required to grow a crop of corn and one of barley as to grow barley on summer fallow. The increase in the yield of barley on fallow was not enough to offset the greater cost of production. The yield of barley on subsoiled and on listed land was either less or only slightly better than on spring or fall plowing.

As was true with other crops, comparable plats yielded less in the south field than in the main one. In the south field in 1922 the listed plats were favored by run-off which increased their yields.

The dry weather in early June, 1922, so injured the fall-plowed plats that they were not able to recover after rains came, and the yields of these plats consequently were low.

TABLE 18.—*Yield of barley in two fields at the Northern Great Plains Field Station following different cultural treatments and various crops for the 8-year period, 1915–1922, inclusive.*

Field, treatment, and previous crop	Number of plats averaged	Yields per acre (bushels)							
		1915	1916	1917	1918	1919	1920	1921	1922	Average
MAIN FIELD										
Disked:										
Corn	3	59.2	26.7	15.5	24.5	14.3	14.3	0	37.1	24.0
Flax	1	38.0	22.5	14.8	9.2	2.7	11.3	0	14.8	14.2
Spring plowed:										
Oats	3	41.9	29.4	19.7	22.3	12.6	6.6	2.4	43.4	22.3
Barley	1	42.6	24.8	17.9	20.8	9.0	0	0	36.0	18.9
Fall plowed: Barley	1	57.0	26.7	19.6	31.3	10.2	0	0	47.1	24.0
Summer fallowed	1	63.2	37.5	17.1	33.5	13.8	20.6	2.5	56.3	30.6
Subsoiled: Barley	1	49.7	29.2	9.6	10.4	8.1	0	0	23.3	16.3
Listed: Barley	1	49.8	30.4	15.6	21.7	5.0	3.3	0	31.7	19.7
Average of all 12 plats		50.3	28.3	16.7	22.3	10.8	8.2	.8	37.6	21.9
SOUTH FIELD										
Spring plowed: Barley	2	50.3	21.0	4.8	0	3.3	0	0	25.6	13.1
Fall plowed: Barley	2	55.5	26.3	2.7	0	2.0	0	0	7.1	11.7
Summer fallowed	2	58.2	29.2	9.3	15.3	16.8	9.1	0	24.7	20.3
Subsoiled: Barley	2	52.6	26.9	4.4	0	2.7	0	0	18.7	13.2
Listed: Barley	2	56.8	30.0	4.6	0	6.9	4.7	0	30.8	16.7
Average of all 10 plats		54.7	26.7	5.2	3.1	6.3	2.7	0	21.4	15.0

CORN

Corn is one of the most important crops that can be grown successfully in this part of the northern Great Plains. It has a double importance, because of its value for grain and fodder and because corn ground affords one of the best preparations in this area for all small-grain crops. The acreage planted to corn has been increasing steadily during the past five years. During the years that corn has been grown at the station it has produced more pounds of grain per acre than any of the small grains. It is the one crop that has not been a complete failure following some particular cultural treatment during the driest years. Corn came nearest to a failure in 1920, but even then it produced more pounds of grain per acre than wheat and oats combined.

Corn is grown on the lighter soil in the main field on 50 plats in combination with small grain, corn, and summer fallow. In the south field it is grown after corn on eight plats and after summer fallow on two plats.

The variety grown on all plats in the rotations is Northwestern Dent. A good strain of this variety was obtained as foundation stock in 1914, and seed has been selected from it each year. A very early strain has been developed. Seed corn usually is selected during the latter part of August and has been picked as early as August 15. The selected seed is thoroughly dried in the fall before it is stored for the winter.

Spring plowing for corn is usually done about May 10, and the crop is seeded between May 15 and May 20. The crop is cultivated usually three times during the season.

Table 19 shows the yield of ear corn in the main field during the eight years 1915–1922. In general, spring plowing after small grain has produced higher yields than fall plowing after small grain, but during favorable seasons the difference in yield is likely to be small. Spring plowing for corn is to be preferred because the work usually is easier, the yields generally are higher, and spring plowing is cleaner than fall plowing. Fall-plowed land in this area is likely to be sown to wheat if the spring is favorable, even though it were intended for corn at the time of plowing. Subsoiling and listing after corn are both inferior to either spring or fall plowing after corn.

Corn has produced a slightly higher yield on summer-fallowed land than on land handled in any other way, but the increase in yield is not enough to compensate for the labor and the loss of the use of the land during the year of fallow except in a dry season, such as 1920.

With either spring or fall plowing there is not much difference in the yield of corn following the different small grains. The desirability of the small grain itself is of much greater weight in its choice than is any effect it may have on a following crop of corn. The yield of corn following corn is higher than following small grain, regardless of the method of tillage.

On the heavier soil in the south field the yields have been less than those from comparable plats in the main field. In this field fall plowing has slightly exceeded spring plowing in yields.

The yields of corn stover are not given in the table, but were slightly heavier than 2,000 pounds per acre. The highest yields were following summer fallow and corn. The highest yield after small grain was on spring plowing.

In rotations where manure is put on for the corn crop the yield of both grain and stover has been higher than in similar rotations where manure was not put on. The influence of the manure has been greater on the stover than on the grain.

TABLE 19.—*Yields of ear corn in the main field at the Northern Great Plains Field Station following different cultural treatments and crops for the 8-year period, 1915–1922, inclusive*

Treatment and previous crop	Number of plats averaged	Yields per acre (bushels)								
		1915	1916	1917	1918	1919	1920	1921	1922	Average
Spring plowed:										
Small grain	29	26.6	37.6	23.1	36.3	24.9	6.9	18.5	35.6	26.2
Corn	1	29.6	39.8	26.7	45.7	28.6	11.4	22.3	39.6	30.5
Fall plowed:										
Small grain	16	26.8	40.2	16.4	33.2	20.0	3.9	13.0	28.5	22.8
Corn	1	26.7	49.1	21.0	44.9	26.9	7.9	22.1	36.6	29.4
Summer fallowed	1	25.7	34.9	28.1	46.6	30.6	24.3	35.3	40.6	33.3
Subsoiled: Corn	1	24.8	44.5	18.7	45.6	29.3	10.1	20.9	35.6	28.7
Listed: Corn	1	27.8	36.6	27.6	37.0	27.1	14.7	18.6	31.6	27.6
Average of all 50 plats		26.7	38.8	21.1	36.1	23.7	6.5	17.3	33.5	25.5

FLAX

Flax is usually the first crop grown when the native sod is broken in this region. It is grown as a cash crop. It is well adapted to seeding on sod, because it can be sown late or after breaking is done in the spring.

Flax is grown on 12 plats; 7 of these are in rotations and 5 are continuously cropped. During the first five years of the experiments a nonwilt-resistant variety of flax was sown in the rotations, and during the first four years in the continuously cropped plats. During the other years a wilt-resistant variety was used. By the end of the third year flax wilt began to appear on all plats, and it was largely responsible for the low yields of 1917 and 1918. Weeds have also been an important factor in the reduction of flax yields. Flax is not able to cope with weeds as well as other crops. The weed that has done most damage in the flax plats is Russianthistle (*Salsola pestifer*). This weed was not a factor in 1915 or 1916, but during the dry years from 1917 to 1921, inclusive, it was an important factor in the reduction of yields. The yields of flax for the eight years 1915–1922 are given in Table 20.

The yields of flax in 1915 were high. With the exception of those plats on which flax follows flax, the land had never grown flax before. The yields for the series of years indicate that the methods under trial have not produced paying yields of flax. All of the flax plats except one, which was in a 5-year rotation, were discontinued in 1921 and 1922. In 1922 flax was placed in two rotations that contain sod crops which precede the flax.

TABLE 20.—*Yields of flax at the Northern Great Plains Field Station following different cultural treatments and crops for the 8-year period, 1915–1922, inclusive*

Treatment and previous crop	Number of plats averaged	Yields per acre (bushels)								
		1915	1916	1917	1918	1919	1920	1921	1922	Average
Disked: Corn	2	18.7	14.8	4.2	0	2.6	0	0	5.6	5.7
Spring plowed:										
Oats	1	15.5	10.2	3.2	0	0	0	0	2.0	3.9
Spring wheat	1	18.2	11.1	4.1	0	0	0	0	2.5	4.5
Corn	2	19.0	14.0	4.4	1.6	.5	.8	0	4.0	5.5
Flax	[1] 1	13.4	5.0	0	0	0	0	0	------	2.6
Fall plowed:										
Corn	1	12.0	12.0	2.3	0	1.3	0	0	1.4	3.6
Flax	[1] 1	13.1	5.2	0	0	0	0	0	------	2.6
Summer fallowed	[1] 1	17.1	10.4	1.3	0	1.3	0	0	------	4.3
Subsoiled: Flax	[1] 1	14.8	6.9	0	0	0	0	0	------	3.1
Listed: Flax	[1] 1	13.2	6.1	0	0	0	0	0	------	2.8
Average of all 12 plats	------	16.1	10.4	2.3	.3	.7	.1	0	3.6	4.1

[1] Discontinued at the end of 1921. The average is for 7 years.

OTHER CROPS

A number of other crops were grown in the rotations, primarily to study their effect upon the following crop, but their yields are not disregarded.

ALFALFA

This crop is grown in one 6-year rotation. The alfalfa is seeded on fall-plowed ground following wheat. It occupies the land for two years in addition to the seeding year and is then broken up. The

alfalfa entirely winterkilled in 1919–20, and a satisfactory stand was not again obtained until 1922. The yield of field-cured hay from 1-year-old and 2-year-old sod in this rotation has averaged about 1,900 pounds per acre.

The variety was Grimm. It was seeded at the rate of 5 to 6 pounds per acre.

BROME GRASS

This grass is sown on disked corn ground, with wheat as a nurse crop. The rate of seeding is 10 to 15 pounds per acre. The brome grass occupies the ground for three seasons after the year of seeding. A satisfactory stand was not obtained during the four seasons 1918–1921, so the yields obtained have been low. Brome grass in this rotation has yielded from 1,000 to 1,600 pounds of hay per acre on the average, depending upon the age of the sod.

POTATOES

Early Ohio potatoes are grown in two 4-year rotations. The potatoes are planted on spring-plowed ground following wheat in one rotation and oats in the other. There has been no marked difference in the results following the two crops. The yields have ranged from 50 to 180 bushels per acre, with average yields between 100 and 110 bushels per acre. In 1921 the potatoes were of poor quality, and only approximately 25 per cent was fit for table use.

SORGO

Sorgo, as a forage crop, appears in one 3-year rotation. The average yield for the eight years 1915–1922 was 3,264 pounds per acre, which is less than that of the same variety (Dakota Amber) in the variety tests, which usually have been sown on spring-plowed ground. Corn in a similar 3-year rotation yielded less than the sorgo during the dry years 1919, 1920, and 1921, but exceeded the sorgo in yield the other years and averaged better for the eight years.

GREEN-MANURE CROPS

Sweet clover, winter rye, and peas are grown in different four-year rotations and plowed under for green manure in preparation for both wheat and oats. Peas are sown on fall plowing, following both oats and wheat; winter rye is drilled into both oats and wheat stubble; and sweet clover is sown on disked corn ground with both oats and wheat as nurse crops. Crops of both winter rye and peas were plowed under each year. Sweet clover produced no crop two years, and only a very light yield two other years. These failures and partial failures were due to drought and winterkilling.

EXPERIMENTS WITH FORAGE CROPS

Investigations of forage-crop production have been conducted since the station was established. Different groups or classes of forage crops and different varieties of the same crop have been under trial. The investigations were conducted in cooperation with the Office of Alkali and Drought Resistant Plant Investigations of the Bureau of Plant Industry from 1914 to 1920, inclusive. A. C. Dillman, for-

merly physiologist in that office, was in charge of the field experiments, and was stationed at Mandan in 1919 and 1920. During 1921 the trials were continued by the Office of Dry-Land Agriculture Investigations without cooperation. In 1922 the work was in cooperation with the Office of Forage-Crop Investigations under the field supervision of H. L. Westover.[10]

ALFALFA AND SWEET CLOVER

Alfalfa probably is the most valuable hay crop that can be grown in this area, because it yields well and makes hay of high feeding value. The severe winters which sometimes occur necessitate the use of hardy varieties. A combination of severe conditions occasionally kills even these, but this does not occur often enough to destroy the value of alfalfa as a hay crop for this area. During the winter of 1919–20, all varieties of alfalfa at the station completely winterkilled except the yellow-flowered variety (*Medicago falcata*), which was 30 per cent killed. This extensive winterkilling was probably because of the dry summer and fall of 1919 and the unusual weather conditions early in the winter. Alfalfa that was located along a coulee and protected by snow did not winterkill.

Table 21 gives the yields of alfalfa, sweet clover, and a mixture of alfalfa and bromegrass for the years these were grown (1914 to 1922, inclusive). In 1915 alfalfa was seeded on native sod broken the previous summer, and a light crop was harvested. During each of the other years until it winterkilled in 1919–20, two crops were harvested. The alfalfa was seeded in drills 6 inches apart and in rows 42 inches apart. The average difference in yield was slight. The hay from the rows was coarser and contained considerable dirt. The rows also required cultivation two or three times during the season. The hay from the drilled plat was free from dirt, and the only labor in connection with it was harvesting.

TABLE 21.—*Yields of field-cured alfalfa, sweet clover, and mixed alfalfa and brome grass hay at the Northern Great Plains Field Station, 1914–1922, inclusive*

[Where no yields are recorded it is because a stand was not obtained during the previous season or because of winterkilling]

Crop and variety	Seeding manner	Yields per acre (pounds)								
		1914	1915	1916	1917	1918	1919	1920	1921	1922
Alfalfa:										
Grimm	Drilled			8,350	3,900	4,610	3,640			
Do	Rows			6,350	4,750	5,290	3,880			
Sweet clover:										
White	Drilled	2,200		5,150			2,510		1,815	
Do	Rows	2,500		1,600	1,300		2,470		4,215	
Yellow	Drilled						2,730		1,730	
Do	Rows						3,390		4,400	
Alfalfa and brome grass mixture	Drilled		2,800	6,950	2,350	2,700	3,520			

Alfalfa in the ordinary tests was sown without a nurse crop at the rate of 5 to 8 pounds per acre in drills 6 inches apart. When sown in rows 42 inches apart, the rate of seeding was approximately 1 pound per acre. The seeding was done with a grain drill having a grass-seeder attachment. With seed of high quality and a favorable season

[10] This report of the experiments with forage crops was prepared by J. T. Sarvis and approved by A. C. Dillman and H. L. Westover.

the lighter rate of seeding has been entirely satisfactory, but under ordinary conditions 7 or 8 pounds per acre seems to be better. This should be sown with a grain drill from the grass-seeder attachment, and without a nurse crop. Alfalfa has been sown fairly early at the station, or soon after wheat seeding. Early seeding is desirable on clean ground, but if the ground is likely to become weedy seeding should be delayed and the land cultivated to kill the weeds.

Different nurse crops, such as wheat, oats, barley, and flax, have been sown with alfalfa. During the period of dry seasons the stands with nurse crops were not satisfactory. In order to insure a stand, alfalfa should be sown alone, as the chances are against obtaining a stand with any nurse crop. Alfalfa is too valuable a crop not to give it the best possible chance for success.

The seedings of alfalfa at the station in 1920 were a failure. This was because of the dry season and weeds. In 1921 a satisfactory stand of alfalfa was obtained, but was lost by winterkilling. The weeds, especially Russian thistles, came up very thick. They were not cut during the season. This is usually the best plan to follow, and a good rule to keep in mind is "to sow alfalfa alone and leave it alone during the first season." If weeds grow thick during the season, they should be burned if possible early in the spring of the next season, or raked into bunches and hauled off the field.

The average yield of alfalfa hay for the 4-year period 1916–1919 was approximately 2½ tons per acre, which is higher than the yield of any other forage crop shown in Table 21. Alfalfa produced a greater tonnage in four seasons than either brome grass or the wheat grasses did in seven.

Many varieties of alfalfa have been tried out for varying periods. Some varieties winterkill even in mild winters. Some varieties have winterkilled to the extent of more than 50 per cent during a winter when Grimm alfalfa showed no winterkilling. The details of the results with the different varieties can not be included in this report.

Sweet clover has been under trial since the station was started. The results obtained have not been entirely satisfactory, as it has not always been possible to get a stand because of drought and weeds, and sometimes it winterkills. The ordinary white sweet clover (*Melilotus alba*) has winterkilled to some extent during most of the winters. Yellow sweet clover (*M. officinalis*) was first sown in 1918. It does not winterkill as much as white sweet clover. In two different four-year rotations sweetclover has been seeded on disked corn ground with wheat and oats as nurse crops in the rotation and the tillage methods of the Office of Dry-Land Agriculture Investigations. In these rotations the sweetclover is turned under for green manure. There was a growth to turn under each year from 1915 to 1922, inclusive, except in 1921 and 1922 because of drought and winterkilling. Ordinary white sweet clover was used in these rotations.

Sweetclover when cut for hay normally lives but two seasons. Therefore, for continuous hay production, it must be seeded every year. In this region it usually produces only a light crop or no crop at all the season it is sown. Since sweet clover normally lives but two seasons, it is usually sown with a nurse crop of wheat, oats, or flax. A better stand is generally obtained under dry-land conditions when it is sown alone at the rate of 10 to 15 pounds per acre, but this requires the use of the land for two years for one crop of hay, and a stand is

no more readily obtained than is a stand of alfalfa, which remains productive for a longer time.

Sweet clover, it seems, should be a secondary crop in a region where alfalfa can be grown successfully. It has not been equal to alfalfa in yield or quality of hay in any year at the station at Mandan. During the period, 1915–1919, inclusive, alfalfa was seeded once for eight crops (two cuttings each season), and sweet clover was seeded four times for four crops.

The yields for 1914 shown in Table 21 were from plantings made that spring. No yields were recorded for 1915, as the 1914 seeding winterkilled and was plowed up in the spring. Where no yields of sweetclover are recorded in Table 21, it is because a stand was not obtained during the previous season or because of winterkilling.

ALFALFA AND GRASS MIXTURES

In Table 21 yields of an alfalfa and brome-grass mixture are shown. The hay was of excellent quality. The yields were lower than those from alfalfa alone, because brome grass gradually crowds out the alfalfa.

A mixture of alfalfa, brome grass, and crested wheat grass was seeded in a field along a coulee in 1919, and the alfalfa did not winterkill in 1919–20. The rate of seeding was approximately 4 pounds of alfalfa, 6 pounds of brome grass, and 6 pounds of crested wheat grass, to the acre. The yields were about the same as those from the alfalfa and brome-grass mixture.

PERENNIAL GRASSES

Table 22 presents the yields produced by smooth brome grass (*Bromus inermis*), crested wheatgrass (*Agropyron cristatum*), slender wheat grass (*A. tenerum*), and western wheat grass (*A. smithii*). The main point of interest is the yield of crested wheat grass, which has been higher than that of any of the others. Crested wheat grass is a bunch grass brought into this country from Siberia some years ago by the United States Department of Agriculture. It has been grown at a number of field stations, and during recent years its value as a hay crop has compared favorably with brome grass and other wheat grasses. Crested wheat grass produces seed of high quality. It can be sown with a drill the same as wheat. It has been sown at the station in rows 42 inches apart. It has also been sown in drills 6 inches apart, 10 to 15 pounds per acre, but no yield records are available from the drilled plats.

Table 22 shows that the average yield of crested wheat grass was higher than that of brome grass or the other wheat grasses. It makes hay of high quality that is readily eaten by stock. Crested wheat grass at Mandan starts growth early in the spring, usually a few days before brome grass, but after it has matured one crop it does not grow any more until fall, when it usually makes some growth which would be of value for pasture.

Brome grass is the cultivated grass most commonly grown. It produces fair crops of hay when first sown, but soon becomes sod-bound and low yielding. It has been sown at the rate of 10 to 15 pounds to the acre, usually by hand or by mixing it with grain. It does not seed readily with a grain drill, but an agitator attachment that makes the grain drill handle brome-grass seed in a satisfactory manner has been made and used at the station.

TABLE 22.—*Yields of perennial grasses at the Northern Great Plains Field Station for the 7-year period, 1916–1922, inclusive*

Kind of grass and manner of seeding	Yields per acre (pounds)								
	1916	1917	1918	1919	1920	1921	1922	Average, 1916–1922	Average, 1916–1919
Brome grass:									
Rows [1]	4,980	2,910	2,490	2,120	470	1,240	1,380	2,227	3,125
Drilled	4,900	1,350	1,450	1,500	440	1,800	1,600	1,863	2,300
Crested wheat grass:									
Rows	3,550	3,200	3,200	3,080	1,250	1,850	1,900	2,576	3,258
Slender wheat grass: [2]									
Rows	4,550	3,000	1,800	1,510					2,715
Western wheat grass: [3]									
Rows	1,450	1,900	1,800	2,340	320	1,050			1,873

[1] Average of 4 plats, 1916 to 1921, inclusive; average of 3 plats in 1922.
[2] This grass was completely dead by the spring of 1920.
[3] This grass was seeded in rows which soon grew together. It was discontinued at the end of 1921.

Slender wheat grass is on the market under the name of western rye grass. It is a short-lived perennial bunch grass. It killed out here during the winter of 1919–20. It does not live under normal conditions more than five or six years. Slender wheat grass can be sown with a grain drill at the rate of from 10 to 15 pounds per acre.

Western wheat grass is the common "wheat grass" or "blue-joint" of the plains. It is a valuable hay grass and yields well in native stands in the lower places. It does not lend itself to cultivation. The seed is low in germination and is not known to be on the market. Western wheat-grass was sown in rows, but it soon spread into a solid mat by means of its rootstocks.

MILLET

Different varieties of millet were grown from 1914 to 1920, inclusive. Millet makes good hay. It can be seeded late. It is valuable as a catch crop. In case of an early failure of some crop, millet can usually be sown. The millet varieties were sown here with a grain drill at the rate of 15 pounds per acre during the latter part of May or the first week in June.

TABLE 23.—*Yields of field-cured hay from drilled plats of seven varieties of millet, Dakota Amber sorgo, Sudan grass, and proso at the Northern Great Plains Field Station for the 7-year period, 1914–1920, inclusive*

Crop and variety	Yields per acre (pounds)								
	1914	1915	1916	1917	1918	1919	1920	7-year average, 1914–1920	6-year average, 1915–1920
Millet:									
Dakota Kursk	4,300	4,800	6,260	1,510	5,320	2,970	2,365	3,932	3,871
Siberian	4,300	4,230	6,330	2,010	4,970	3,095	3,410	4,049	4,008
Gold Mine		3,700	7,100	1,460	4,270	4,200	2,695		3,904
Hungarian	3,300	3,900	5,860	1,100	3,710	4,450	1,595	3,416	3,436
Kursk No. 5	4,240	4,470	6,720	1,650	3,220	2,670	2,200	3,596	3,488
Common	3,000	2,800	5,500	1,930	3,990	2,120	1,980	3,046	3,053
Golden (German)		6,230	10,000	1,650	2,380	3,430	1,760		4,242
Dakota Amber sorgo	6,760	5,300	6,530	1,320	4,550	5,560	1,265	4,469	4,088
Sudan grass	3,140	2,730	3,380	1,650	2,940	3,310	1,265	2,631	2,546
Proso: Early Fortune	3,080	2,690	5,170	2,560	1,460	1,060	2,090	2,587	2,505

In Table 23 are shown the yields of millet from drilled plats, as compared with Dakota Amber sorgo and Sudan grass seeded in the same manner. The Golden (German) millet has produced the highest yield. It was very late, however, and the hay was very coarse. The Dakota Kursk and the Siberian varieties make better hay and are earlier than the Golden. The broomcorn, or hog millet (proso), produced the lowest yields, and the hay was inferior. Sorgo sown in drills made the highest yield, and the hay was of good quality.

SORGHUMS AND CORN

A number of varieties of sorghum have been grown in rows for comparison with corn. This area is too far north for sorghums to produce to the best advantage. The highest average yield of sorghum at Mandan has been but slightly higher than the lowest average yield at Ardmore, S. Dak.

The sorghums were planted at the rate of approximately 8 pounds per acre in rows 42 or 44 inches apart. They were on spring-plowed ground after small grain, except in 1914 and 1915, when they were on native sod broken the previous season. Sorghum varieties were not planted in 1921.

Table 24 shows the yields of sorghum varieties, corn, and Sudan grass. The highest yield per acre was produced by Red Amber sorgo, and the lowest yields by Sudan grass, feterita, and kaoliang. Red Amber sorgo usually does not mature at Mandan, although it makes very good fodder. Its feeding value would no doubt be exceeded by corn, which produces fewer tons per acre. Dakota Amber sorgo is a very early variety and can usually be depended upon to mature seed. It is, no doubt, the best forage sorghum for this area. Sudan grass makes excellent hay, but its yield has been so low that it does not compare favorably with the other crops. A few acres of sorgo on a farm provides a valuable variety in the forage. Sorgo is readily eaten by stock, especially horses.

TABLE 24.—*Yields of sorghum, corn, and Sudan grass (grown in rows) at the Northern Great Plains Field Station during the 9-year period, 1914–1922, inclusive*

Crop and variety	Yields per acre (pounds)									
	1914	1915	1916	1917	1918	1919	1920	1921 [1]	1922	Average for years grown
Sorghum:										
Dakota Amber	5,680	2,700	4,880	1,410	3,300	3,085	2,660	4,850	3,105	3,519
Minnesota Amber	6,370	1,830	4,160	3,220	4,240	4,115	2,950	-------	6,345	4,154
Red Amber	7,040	3,760	7,430	3,100	4,240	4,880	2,030	-------	6,705	4,898
Kaoliang	-------	2,160	4,410	2,700	2,330	-------	1,745	-------	-------	2,669
Feterita	-------	2,180	3,650	1,690	[2] 1,060	3,715	-------	-------	-------	2,809
Corn: Northwestern Dent	4,210	4,070	4,770	3,760	4,300	2,560	2,000	3,050	5,130	3,761
Sudan grass	3,215	1,830	4,180	1,460	4,950	2,560	1,110	-------	3,645	2,869

[1] Yields from Dakota Amber sorgo and corn on spring plowing in rotation plats.
[2] Very low stand; yield not included in average.

SILAGE CROPS

Corn, sunflowers, and sorgos have been grown in a silage test for two years. Sorgo has produced the highest silage weight per acre. Both corn and sorgo have exceeded sunflowers in weight of dry matter per acre. Corn usually produces enough ears in this section

to make it exceed any of the other silage crops in feeding value. On the average, corn perhaps is the best forage crop for either fodder or silage.

OTHER FORAGE CROPS

A number of other forage crops, such as field peas, rape, chick-peas, vetch, soy beans, and cowpeas, have been grown. None of these produced yields that compared favorably with the millets, sorgos, or alfalfa.

SUMMARY OF FORAGE-CROP EXPERIMENTS

Alfalfa is the best legume hay that has been grown at the station. Only hardy varieties should be grown, as common alfalfa ordinarily will winterkill in this area, and during a combination of severe conditions even the most hardy varieties may be killed.

Sweetclover does not yield on the average as much as alfalfa. It winterkills, to some extent, nearly every year. It is difficult under dry-land conditions to get a stand of sweetclover, and it must be seeded every year.

Brome grass produces good hay, but does not yield as heavily as crested wheatgrass, which produces hay of high quality.

Millets are of value as crops that can be sown late. Dakota Kursk, Siberian, and Gold Mine, are the best varieties for this area. They may be exceeded in yield, in favorable seasons, by later-growing varieties, but the coarse hay from these latter is of inferior quality.

Corn and sorgo have been grown for both fodder and silage. Red Amber sorgo has produced the highest yield per acre. It is no doubt surpassed by corn in feeding value. Dakota Amber sorgo has matured regularly, and is the most satisfactory forage sorghum for conditions similar to those in this region. Sudan grass makes a fodder of good quality, but its yield is low.

VARIETAL TESTS WITH CORN

Varietal tests with corn have been conducted in cooperation with the Office of Cereal Investigations during the eight-year period from 1915 to 1922, inclusive. Twelve flint and 18 dent varieties have been involved in these tests.

During the three years 1915–1917 the varieties of corn were on heavy soil in the south field. From 1918 to 1922, inclusive, they were on light soil in field M, which adjoins the main field in which the crop rotations are located. The crop-rotation results show the lighter soil to be the better for corn. According to those results yields would have been obtained in 1917 if the varieties had been on the lighter soil that year.

The varietal tests usually have been on spring-plowed ground following small grains. The cultural methods have been the same as in the crop-rotation work. The planting has been done with a two-horse planter, the rows being drilled 44 inches apart and the plants thinned to 18 inches apart in the row. Planting dates have been confined to narrow limits, from May 18 to May 23, an extreme range of five days in the eight years. The harvesting, in most cases, was done with a corn binder. In 1921 the flint varieties were so short that it was necessary to cut them by hand, and in 1922 all varieties were husked from the standing stalks.

Notes on maturity are not in any way complete, but it appears that on the whole, the flints are earlier than the dents. The flints are mostly low-growing and have a tendency to sucker freely, whereas the dents grow taller and are more or less free from suckers. These differences affect the ease with which each group may be harvested. The dent varieties, as a group, are harvested readily with a corn binder; but the flint varieties, with the exception of some of the late ones, such as Mercer and Rainbow, are difficult to harvest in this way.

The annual and average yields of the varieties of corn that have been grown from six to eight years are given in Table 25. This list includes all the higher yielding of the best adapted varieties.

The best-yielding flint varieties are Dakota White, Gehu, and White Ree. These are also the earliest of the flints. There is so little difference in the yield of these three varieties that it is impossible to state that one is superior to the others in yield of grain. Nine other flint varieties have been tested for periods varying from one to three years. Among the later varieties which are regarded well farther east and south are Mercer and Rainbow, but these have not compared well with the earlier varieties in production of grain.

The leading dent varieties in production of ear corn are Northwestern, Payne White, Minnesota No. 13, and Rustler. For this section the first two may be considered as medium-early varieties and the last two as medium-late varieties. The Northwestern dent under trial was the local-station strain described in connection with the rotation and tillage work. It is perhaps one of the most dependable dents for this section and has the highest average yield of any of the dent varieties tested. Minnesota No. 23 is one of the earliest dents but has not proved to be a good yielder. Of the medium-late varieties Minnesota No. 13 is perhaps the most popular in this section. It grows to more than average height, the ears are high, and it is practically free from suckers.

The highest yielding variety of flint has an 8-year-average acre yield of 25.8 bushels and the highest yielding variety of dent an average of 23.5 bushels for the same period.

The yields of fodder or stover have not always been determined in these trials. The incomplete records show yields as high as 3 tons of field-cured fodder per acre. The highest yields of fodder generally have been from the flints.

TABLE 25.—*Yields of ear corn of the varieties tested at the Northern Great Plains Field Station six or more years during the 8-year period, 1915–1922, inclusive*

Group and variety	Yields per acre (bushels)									
	1915	1916	1917	1918	1919	1920	1921	1922	6-year average, 1917 to 1922	8-year average, 1915 to 1922
Flint:										
Dakota White	20.0	36.8	0	38.0	26.8	23.1	26.7	35.0	24.9	25.8
Gehu	16.6	38.0	0	31.8	24.5	17.8	26.5	35.3	22.7	23.8
White Ree	------	------	0	35.7	25.5	18.0	25.2	35.3	23.3	------
Dent:										
Northwestern	21.5	27.1	0	33.2	26.1	12.3	30.5	37.0	23.2	23.5
Rustler	29.5	33.3	0	19.7	20.0	15.7	25.2	23.4	17.3	20.9
Payne White	------	------	0	28.2	30.3	13.6	30.1	29.4	21.9	------
Minnesota No. 13	------	------	0	22.6	23.7	8.1	22.7	31.8	18.2	------
Minnesota No. 23	------	------	0	11.9	18.9	7.2	19.3	21.5	13.1	------

SOIL-MOISTURE INVESTIGATIONS

Limitation of the available water supply being the chief factor in the control of yields in this section, soil-moisture investigations have been an integral and important part of the work throughout. These investigations have been for the purpose of determining the effects of cropping and cultural practices on the storage and retention of water in the soil, to determine to what extent differences in yields from different cultural practices were due to differences in the water supply afforded by them, and to learn the fundamental principles of water storage and use in dry farming. This work is correlated with similar work at the other field stations of the Office of Dry-Land Agriculture Investigations.

A total of about 9,000 determinations of soil moisture has been made in connection with the agronomic work of the station. The results will not be discussed in this report.

INVESTIGATIONS WITH FLAX AND CEREALS [11]

The flax and cereal investigations at the Northern Great Plains Field Station consist of varietal and cultural experiments, including studies of dates and rates of seeding and the breeding and selection of superior varieties. This work is conducted cooperatively by the Office of Cereal Investigations and the Office of Dry-Land Agriculture Investigations. Experiments with flax were begun in 1914, and experiments with wheat, oats, and barley were added in 1916.

EXPERIMENTS WITH FLAX

The seed-flax crop of the United States is grown in about the same area as hard red spring wheat, including North Dakota, Minnesota, northeastern South Dakota, and northeastern Montana. This station is in the west-central part of this area, and the results of investigations with flax are believed to be applicable over a large part of the flaxseed-producing area.

FLAX ON BREAKING

Flax is still grown to a large extent as the first crop on newly broken sod lands. On sod, flax does better than most other farm crops. The experimental flax plats at the station were on breaking for three consecutive years, 1914, 1915, and 1916. The results of these experiments were published in 1920.[12]

These experiments were conducted under unusually favorable conditions of soil and rainfall, and the yields obtained were nearer the optimum to be expected than the average.

The land used for the experiments in 1914, 1915, and 1916 was broken and backset the previous year in each case. This treatment provided almost ideal conditions for flax, as the soil was free from weeds, moisture was stored, and the sod was partly rotted so that a good seed bed could be prepared.

Two types of flax are grown commonly for seed production: (1) The European seed-flax type, having blue flowers, large branched stems, and large brown seeds; and (2) the short-fiber type, having

[11] By J. C. Brinsmade, jr., Assistant Agronomist, Office of Cereal Investigations.
[12] Clark, Charles H. Experiments with flax on breaking. U. S. Dept. Agr. Bul. 883, 29 p., 3 fig. 1920.

blue flowers, finer stems, and small brown seeds. The latter type is represented by North Dakota Resistant (N. D. R.) No. 114 (C. I. No. 13),[13] and Primost (C. I. No. 12), which are both more or less resistant to flax wilt. The European seed type includes most of the named varieties and the common unnamed flax of the seed-flax area.

Detailed data on yield, agronomic characters, and oil production of 14 varieties of flax grown on breaking at Mandan in 1914, 1915, and 1916 are presented in Department Bulletin No. 883. All varieties of the European seed-flax type yielded better than the short-fiber varieties. The leading variety, Reserve (C. I. No. 19), averaged 17 bushels to the acre, with an average oil yield of 342 pounds to the acre. Select Riga (C. I. No. 2), with practically the same yield of seed, showed a higher oil content, averaging 354 pounds of oil to the acre. Damont (C. I. No. 3), Select Russian (C. I. No. 1), and Frontier (C. I. No. 17) produced practically the same yields of seed and oil as Reserve. North Dakota Resistant No. 114 averaged only 12.2 bushels to the acre, with 233 pounds of oil. The yield of Primost was still lower. Varieties of the seed-flax type are best adapted to new lands.

In two years out of three a seeding rate of 20 pounds per acre produced slightly better results than either a higher or lower rate, but the results of the experiment are not conclusive. On a well-prepared seed bed under semiarid conditions, there appears to be no advantage in seeding at a heavier rate than 20 pounds.

Experiments indicate an advantage in early seeding on clean new lands, although results of three seasons do not furnish sufficient data to warrant definite conclusions. The highest average yields were obtained from seedings between May 1 and May 18. Seedings on June 1, 1914, and on June 15, 1916, made decidedly lower yields than earlier seeding in each of these years.

FLAX ON OLD GROUND

The flax experiments at this station have been modified since 1916 to meet the problems of weed control and flax diseases, especially flax wilt, which are becoming of increasing importance on the older-cultivated lands. Experiments in different methods of tillage have been conducted to determine the best methods of weed control. Extensive plant-breeding operations also have been carried on to develop high-yielding wilt-resistant varieties.

During the years 1917–1922 in which the flax experiments were on old land, climatic conditions were exceptionally unfavorable. The previous treatment and preparation of the land for the plat experiments were not the same every year. In two seasons the flax varietal experiments were on fallow ground; two seasons they followed corn; one season they followed potatoes; and one season they followed sorgo. The land often was very weedy, as the dry seasons favored the growth of Russian thistles. In some cases the experiments were on land that previously had been cropped to flax. The land generally was double-disked and harrowed just before seeding in the spring. The previous cropping and treatment were essentially the same for all plats in each experiment in any one year.

[13] Accession number of the Office of Cereal Investigations.

The results from the flax varietal experiments in the years 1914–1916 show what may be expected of flax on breaking under favorable conditions. The results from the flax varietal experiments from 1917 to 1922, inclusive, indicate what may be expected of flax on old land under exceptionally dry conditions. The average acre yield of all varieties on breaking during 1914, 1915, and 1916 was 14.8 bushels. The average acre yield of all varieties grown on old land in the years 1917 to 1922, inclusive, was 4.1 bushels. The season of 1921, when the crop was a total failure, is included in this average.

The average acre yields of five varieties for the 6-year period from 1917 to 1922, inclusive, were as follows: Reserve (C. I. No. 19) 4.5 bushels; Damont (C. I. No. 3) 4.3 bushels; North Dakota Resistant No. 52 (C. I. No. 8) 4.0 bushels; North Dakota Resistant No. 114 (C. I. No. 13) 3.9 bushels; and, Primost (C. I. No. 12) 3.8 bushels. The large-seeded varieties, Reserve and Damont, again yielded better than the small-seeded varieties, North Dakota Resistant No. 114 and Primost.

A rate-of-seeding experiment similar to that on breaking was conducted on old land during the years 1917–1921. On account of the dry seasons, the differences in yield were not large enough to be significant. The results indicate, however, that on a loose seed bed on old land slightly better yields may be expected from seeding 25 pounds per acre than from less.

Experiments on the date of seeding flax on old land have indicated the advantage in dry seasons of giving the land thorough cultivation with a disk harrow before seeding, in order to destroy weeds, especially the Russianthistle, which is the worst weed in the dry-land area. Plats disked twice or three times at intervals of two weeks between cultivations and sown May 15 or June 1 were more free from weeds and the yield of seed was higher than from plats disked only once and sown April 15 or May 1.

Experiments with flax grown continuously on the same land have indicated that North Dakota Resistant No. 114 can be depended upon to produce a crop on flax-sick soil.

Investigations with flax canker have indicated that excessive heat will girdle the plants at the soil line, causing them to fall over and die. This subject is treated fully in Department Bulletin No. 1120.[14]

Flax varieties obtained from many parts of the world have been grown in nursery rows and classified according to height, earliness, type of plant, resistance to wilt, yield of seed, and other characters. These nurseries have furnished valuable material for breeding new flax varieties.

FLAX AND CEREAL MIXTURES

Experiments in growing flax in mixture with wheat, oats, and barley were carried on in 1917 and 1918. A fair yield of the mixed crop was obtained in 1917. In 1918 the flax was a failure both in mixture and where sown alone. The mixture of flax with Marquis spring wheat gave better results than the mixture of flax with oats or barley. The yield of the mixed crop in 1917 was 1.5 bushels of flax plus 9.9 bushels of wheat, as compared with 7.2 bushels of flax alone and 13.3 bushels of wheat alone.

[14] Reddy, C. S., and W. E. Brentzel. Investigations of heat canker of flax. U. S. Dept. Agr. Bul. 1120, 18 p., 4 fig., 5 pl. 1922. (Literature cited, p. 17–18.)

EXPERIMENTS WITH CEREALS

EXPERIMENTAL CONDITIONS

It is important to determine what varieties of cereals are best adapted to the locality. In crop-rotation experiments a single variety of each crop is grown under different rotation and tillage methods to determine the best farm practice in soil preparation. In varietal experiments with cereals different varieties are grown under the same soil conditions to determine the best variety for the locality. Varietal experiments with wheat, oats, and barley were begun at Mandan in 1916. The previous treatment of the land varied in different years. The wheat varietal experiments in 1916 were sown on flax land plowed the previous fall; in 1917 they were sown on spring-plowed cornland, in 1918 on breaking, in 1919 after corn, in 1920 after millet, and in 1921 and in 1922 after corn. The land in every case was double-disked and harrowed in the spring before seeding.

The oat and barley varieties in 1916 were sown on fall-plowed flax land, in 1917 on breaking, in 1918 on fallow, in 1919 after sorgo and millet grown in cultivated rows, in 1920 after sorgo grown in cultivated rows, in 1921 after Llamantia in rows, the ground having been plowed early in the fall; and in 1922 after sunflowers, sorgo, and corn grown in cultivated rows. The land was double-disked and harrowed before seeding each year, except in 1920, when a spring-tooth harrow was used to stir the soil. Although the previous crop and preparation of the soil varied from year to year, all varieties in each experiment received the same treatment.

EXPERIMENTS WITH WHEAT

Annual and average yields of the spring-wheat varieties grown in plats from 1916 to 1922, inclusive, are shown in Table 26. Four varieties of common wheat, Marquis, Preston, Power, and Haynes Bluestem, and two amber durum varieties, Kubanka No. 8 and Arnautka, were grown each year from 1916 to 1921, inclusive.

TABLE 26.—*Annual and average yields of varieties of spring wheat grown at the Northern Great Plains Field Station during the 7-year period, 1916 to 1922, inclusive*

Class, group, and variety	C. I. No.	Yields per acre (bushels)							Average		
		1916	1917	1918	1919	1920	1921	1922	1916 to 1922	1920 to 1922	1921 and 1922
Fife: HARD RED SPRING											
Marquis	3641	12.5	11.4	24.9	13.2	7.6	3.8	16.7	12.9	9.4	10.3
Power	3697	8.3	14.9	23.7	13.1	8.2	1.8	18.5	12.6	9.5	10.2
Red Bobs	6255						5.1	20.0			12.6
Ruby	6047						4.9	16.4			10.7
Bluestem:											
Haynes	2874	6.5	10.3	17.1	11.6	6.8	.8				
Preston:											
Kota	6248					9.2	4.4	18.6		10.7	11.5
Preston	3081	9.7	13.8	19.9	14.4	7.8	5.2	17.5	12.6	10.2	11.4
Miscellaneous:											
Hard Federation	4733						6.7	18.1			12.4
Kubanka: DURUM											
Acme	5284				15.6	6.7	3.8	18.6		9.7	11.2
Arnautka	4064	11.4	13.6	24.8	10.9	6.7	3.3	16.0	12.4	8.7	9.7
Kubanka	1440						4.0	19.6			11.8
Kubanka No. 8	4063	13.9	12.5	23.2	10.9	7.3	4.3	20.0	13.2	10.5	12.2
Kubanka No. 74								19.8			
Mindum	5296							19.9			
Monad	3320					6.8	4.7	20.3		10.6	12.5
Nodak (Kubanka No. 98)	6519						4.7	19.2			12.0
Peliss:											
Peliss	1584						5.5	16.8			11.2

Kubanka No. 8, a pure-line selection from Kubanka, leads all varieties in the seven-year average yield. Marquis ranks second, leading all the other varieties of common wheat. The differences in yield are not large enough to have much significance. Kota, an awned rust-resistant variety of spring common wheat, first included in the experiments in 1920, outyielded all other varieties in that year. It is of good milling and baking qualities, is rather resistant to drought, but has weak straw. Haynes Bluestem gave the lowest yield nearly every year and was discarded after 1921. The relatively low yield of Haynes Bluestem is typical of the results obtained by farmers in the vicinity of Mandan.

EXPERIMENTS WITH OATS

Yields of six varieties of oats grown from 1916 to 1922, inclusive, are shown in Table 27. Fair yields were obtained every year except 1921, when all varieties except Sixty-Day failed to mature any grain. Sixty-Day is a short, early, yellow oat well adapted to North Dakota. Golden Rain is a yellow oat about 4 to 8 inches taller and a week or 10 days later than Sixty-Day. It has produced the highest average yield during the seven-year period. Victory, a white oat of about the same height and time of maturity as Golden Rain, is second in average yield. This variety, because of its color, is preferred by many farmers as a market grain. Both Golden Rain and Victory produced considerably more straw than Sixty-Day. Swedish Select is a white oat slightly shorter and earlier than Victory but not consistently as good a yielder.

White Tartar (White Russian), a white side oat ripening a week or 10 days later than the midseason varieties, has produced the lowest yield in four out of seven years. Its average acre yield for the seven-year period has been about 9 bushels less than that of the two best varieties, Victory and Golden Rain.

TABLE 27.—*Yields of grain and straw of six varieties of oats at the Northern Great Plains Field Station during the 7-year period, 1916–1922, inclusive*

Group and variety	C. I. No.	Yields of grain per acre (bushels)								Average acre yield of straw (pounds)
		1916	1917	1918	1919	1920	1921	1922	Average	
Early yellow:										
Sixty-Day	165	42.2	37.5	34.7	22.1	23.5	1.9	40.8	29.0	1,069
Midseason yellow:										
Golden Rain	493	48.7	40.3	37.2	20.0	29.3	0	46.7	31.7	1,349
Midseason white:										
Victory	560	46.7	41.1	35.3	17.0	28.9	0	47.6	30.9	1,308
Swedish Select	134	37.8	37.0	34.1	16.9	29.7	0	46.3	28.8	1,199
Early Mountain	656	49.4	29.1	27.4	18.3	22.5	0	35.4	26.0	1,288
Late side:										
White Tartar	551	43.6	34.2	16.9	16.4	19.7	0	21.4	21.7	1,168

EXPERIMENTS WITH BARLEY

Yields of the six barley varieties grown from 1916 to 1922 are shown in Table 28. The two-rowed barleys all yield better than the six-rowed.

White Smyrna, though very early and producing the highest average yield of grain, is too short to harvest readily. Hannchen barley is taller, easier to handle, somewhat later than White Smyrna, and yields practically as well. Svanhals, or Swanneck, is about the same height as Hannchen, ripens at about the same time, and yields practically as well.

Mariout and Coast, though early and of satisfactory height, have tough beards that stick to the seed and interfere with seeding. Manchuria, though well adapted to the more humid localities farther east, is nearly always the poorest yielder at Mandan.

TABLE 28.—*Yields of grain and straw of six varieties of barley at the Northern Great Plains Field Station during the 7-year period, 1916–1922, inclusive*

Group and variety	C.I. No.	Yields of grain per acre (bushels)							Average acre yield of straw (pounds)
		1916	1917	1918	1919	1920	1921	1922	Average
Two-rowed:									
White Smyrna	195	29.0	23.1	25.0	21.8	11.3	7.7	40.8	22.7	1,165
Hannchen	531	31.0	20.4	25.3	20.4	16.0	0	43.5	22.4	1,207
Svanhals	187	26.2	20.3	26.2	18.7	18.1	0	43.1	21.8	1,340
Six-rowed:									
Coast	690	25.8	16.8	24.5	17.5	11.4	2.9	42.1	20.1	1,050
Mariout	261	25.8	14.5	22.6	13.6	10.8	7.3	33.5	18.3	949
Manchuria	354	20.8	8.1	17.6	13.7	11.4	.6	34.8	15.3	996

COOPERATIVE GRAZING EXPERIMENT [15]

PLAN OF THE EXPERIMENT

The grazing of livestock, especially cattle, on the native range of the northern Great Plains has been and will no doubt continue to be an important industry. A large percentage of the land in this area is unfitted for cultivated crops, either because of its location or its physical character.

The cooperative grazing experiment is conducted by the Office of Dry-Land Agriculture Investigations in cooperation with the North Dakota Agricultural College. The United States Department of Agriculture furnishes the land and equipment and conducts the field details of the experiment; the agricultural college provides the cattle.

The field plan of the pasture is shown in Figure 7. The section of land where the pastures are located is approximately 2 miles south of the station buildings. The soil of the pasture section is somewhat similar to that of the south field.

The grazing experiment was started with preliminary work in 1915, but the grazing of four pastures with varying intensity, according to the plan of the experiment, began in 1916. These pastures were put under a system of continuous grazing, and this system has been continued on them. The pastures are 100, 70, 50, and 30 acres in size and are grazed at the rate of one steer to 10, 7, 5, and 3 acres, respectively. In order to obtain different intensities of grazing, a variation was made in the size of the pastures rather than in the number of cattle in each pasture.

[15] By J. T. Sarvis, Associate Agronomist.

In 1917 a 70-acre pasture for deferred and rotation grazing was established. It is referred to as the rotation pasture. This is the system of grazing that has been developed by the Forest Service of the United States Department of Agriculture. Grazing started on this rotation pasture in the spring of 1918.

During 1918 and 1919 the rotation pasture was grazed by the same number of cattle as the other pastures. In 1920 the number was increased to 15. It carried 17 head in 1921 and 16 head in 1922.

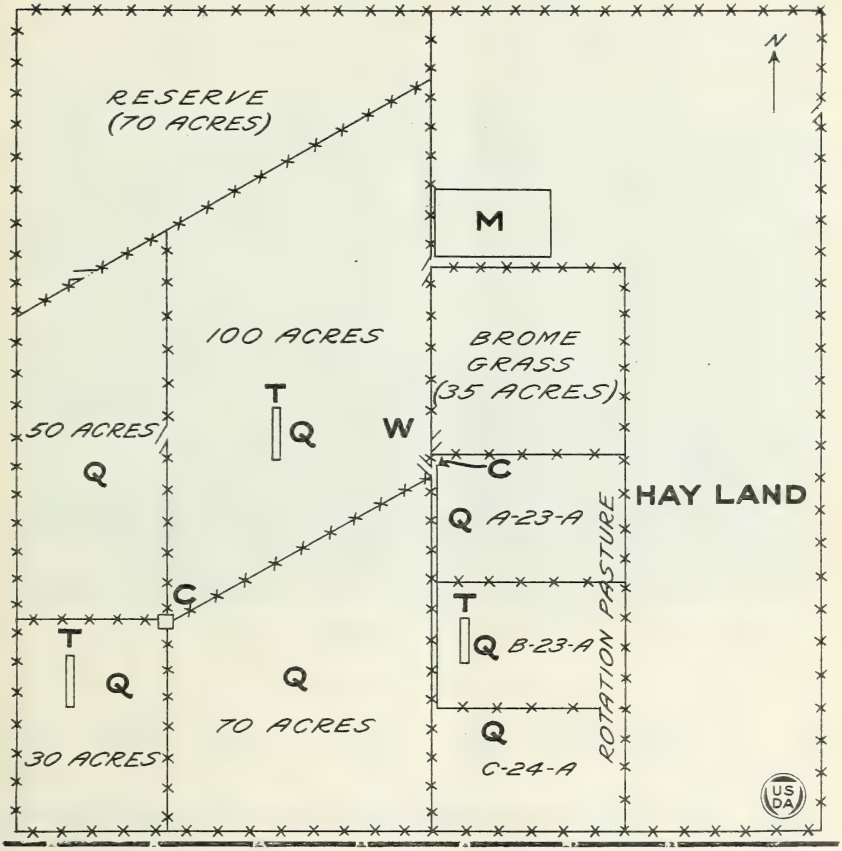

FIG. 7.—Field plan of the pastures used in the cooperative grazing experiment at the Northern Great Plains Field Station: *T*, isolation transect; *Q*, mapped quadrats; *C*, corrals and water trough; *W*, deep well; *M*, mowing experiment

This is approximately the number it should carry which is at the rate of 4.375 acres per head.

A cultivated pasture of bromegrass has been established, and was grazed for the first time in 1923. The pasture designated as the "reserve" is used to carry the cattle before the experiment opens in the spring and after it closes in the fall. It is also used during the grazing season to carry extra steers to be used as replacements in case of accident to any of those in the experiments. The cattle from the small pastures are turned on the reserve when their supply of forage is exhausted.

The plan of grazing the rotation pasture is shown in Table 29. This plan illustrates the application and management of deferred and rotation grazing. The 70-acre area is divided by cross fences into three divisions, all approximately the same. The divisions are designated as A, B, and C. When this pasture was first grazed in 1918, division A was grazed in the spring; division B in the summer; and division C was allowed to mature its crop normally and was grazed in the fall. In 1919 division B was grazed first, division A second, and division C was again deferred until third before grazing, or after the crop had matured without disturbance. During the following seasons divisions A and B were in turn treated as was division C in 1918 and 1919. The grazing starts in the spring of each season, so that a division that has been deferred until fall for two successive years is not grazed first. This is done so that any seedlings that may have started from the second year's seeding may have a chance to become more firmly established before the division is grazed.

As far as has been possible to determine, there has been no measurable increase of any of the species by reseeding in the rotation pasture. This was no doubt influenced to some extent by the very unfavorable seasons. The advantage gained in this region by this system of grazing is in the physiological effect upon the plants.

This experiment does not take into consideration winter grazing, which should not be depended upon in this section of the plains. The seasonal period of grazing has been five months during the summer. Grazing has started from May 15 to June 1 and continued to October 15 or November 1. Four years of the seven the seasonal grazing started in May and three years on June 1.

TABLE 29.—*Plan of grazing the deferred and rotation pasture at the Northern Great Plains Field Station for the 6-year period, 1918–1923, inclusive*

Year	Divisions of pasture, and periods of grazing			Year	Divisions of pasture, and periods of grazing		
	A	B	C		A	B	C
1918	Spring	Summer	Fall.	1921	Summer	Fall	Spring.
1919	Summer	Spring	Do.	1922	Fall	Summer	Do.
1920	Spring	Fall	Summer.	1923	do	Spring	Summer.

The cattle used in the grazing experiment are 2-year-old grade steers of the standard beef breeds. Figure 8 illustrates the type used during 1922.

The 2-year-old beef steer was decided upon as the unit, as (*a*) he seemed to be most used by ranchmen figuring on this question; (*b*) he has about the average capacity for consumption between yearlings, cows, and large steers; (*c*) he is not disturbed like the heifer, by periods of œstrum or by calving during the trial.[16]

The cattle are weighed individually at the end of regular 30-day periods. Whenever the grazing season starts before June 1 they are weighed at the start in May and again on May 31. This is done so the periods will correspond to the months. At the beginning and close of the season the cattle are weighed on three consecutive days.

[16] Shepperd, J. H. Carrying capacity of native range grasses in North Dakota. *In* Jour. Amer. Soc. Agron., v. 11, p. 129–142, pl. 3–5. 1919.

The initial and the final weights are the averages of the three weighings. The cattle are always weighed at the same period of the day. In order to keep a record of the individual steers, they are branded with serial numbers.

After the initial weights are obtained the cattle are divided into uniform lots for the various pastures. The initial weight of 10 steers is about 7,500 pounds. The cattle have free access to water at all times.

FIG. 8.—Two-year-old steers used in the cooperative grazing experiment at the Northern Great Plains Field Station. This lot was on the 70-acre pasture. Photographed in October, 1922

GAINS OF THE CATTLE

The grazing capacity of a pasture is determined indirectly by the gains of the cattle. If the cattle continue to make gains that are relatively high the native vegetation is not being damaged by overgrazing. The grazing experiment has been in progress long enough to establish the maximum gains per head that may be considered normal. The seasonal gains of the cattle in the 70-acre pasture are given in Table 30. This pasture has produced the maximum gains per head. The quantity of available feed for grazing has not been a limiting factor in the production of gains in this pasture. While the total gain for the season is the measure of ultimate importance, the gains for the various months are also significant. Table 30 shows that the highest gains are made during June, and a slight loss is recorded for October. The weather influences the gains during October. Cold weather often occurs in that month, and the cattle lose weight because of shrinkage.

The average gains of the cattle from all pastures are shown in Table 31 for the period the experiment has been in progress. The highest gains per head are made in the 100-acre and 70-acre pastures.

The gains in the rotation pasture are between those in the larger and the smaller pastures. The 30-acre pasture gives the lowest gains per head, but the gains per acre in it are high. A table similar to Table 31, but for the years the rotation pasture has been in operation, would show the same relative gains for the various pastures. If only the years 1920, 1921, and 1922, were considered for all pastures, the same relative ranks would still obtain except that the rotation pasture would show the highest gain per acre.

TABLE 30.—*Gains of 2-year-old steers*[1] *on the 70-acre pasture at the Northern Great Plains Field Station for the 7-year period, 1916–1922, inclusive*

Year	Total monthly gains or losses[2] (pounds)						Total gains (pounds)— Seasonal					Number	
	May	June	July	August	September	October	Per pasture	Per head	Per acre	Per 100 pound of live weight	Per head, daily	Steers	Days grazed
1916	------	1,035	885	610	635	−50	3,115	311.5	44.5	41.1	2.08	10	150
1917	140	1,010	445	555	370	−390	2,130	213.0	30.4	27.3	1.37	10	155
1918	595	1,055	575	330	495	130	3,180	318.0	45.4	45.0	2.05	10	155
1919	------	1,510	420	700	310	50	2,990	299.0	42.7	37.4	2.14	10	140
1920	------	1,350	690	495	595	−70	3,060	306.0	43.7	39.2	2.04	10	150
1921	560	990	590	750	100	185	3,175	317.5	45.4	44.5	2.12	10	150
1922	580	1,110	920	400	380	25	3,415	341.5	48.8	50.3	2.28	10	150
Average	[3] 469	1,151	646	549	412	−17	[4] 3,009	300.9	43.0	40.9	2.01	10	150

[1] Yearlings were used in part in 1916 and 1918. The gains shown have been reduced to a 2-year-old basis and differ but slightly from those actually made. When yearlings were used, the number of cattle was increased to bring the total initial weight up to about 7,500 pounds.
[2] A minus sign (−) indicates a loss.
[3] Average period of 10 days for the four seasons that the cattle were started on pasture in May.
[4] This average does not equal the sum of the monthly averages because the grazing periods were not uniform.

TABLE 31.—*Gains of 2-year-old steers*[1] *on the continuously grazed and rotation pastures at the Northern Great Plains Field Station*

[The gains shown for the continuously grazed pastures are for the 7-year period, 1916–1922, inclusive; those for the rotation pasture (70 acres) are for the 5-year period, 1918–1922, inclusive]

Pasture	Average total monthly gains, or losses[2] (pounds)						Average total gains[3] Seasonal					Average number of—	
	May	June	July	August	September	October	Per pasture	Per head	Per acre	Per 100 pounds of live weight	Per head, daily	Steers per pasture	Days grazed
100 acres	[4] 400	1,086	659	514	417	45	2,949	294.9	29.5	39.9	1.97	10	150
70 acres	[4] 469	1,151	646	549	412	−17	3,009	300.9	43.0	40.9	2.01	10	150
50 acres	[4] 441	1,161	629	550	148	−204	2,535	253.5	50.7	34.7	1.71	10	148
30 acres	[4] 394	1,070	480	206	[5] −218	[6] −285	1,816	181.6	60.5	24.5	1.62	10	112
Rotation, 70 acres	[7] 865	1,379	856	662	368	−6	3,778	277.8	54.0	37.7	1.86	13.6	149

[1] Yearlings were used in part in 1916 and 1918. The gains in the above table have been reduced to a 2-year-old basis and differ but slightly from those actually made. When yearlings were used, the number of cattle was increased to bring the total initial weight up to about 7,500 pounds.
[2] A minus sign (−) indicates a loss.
[3] These averages do not equal the sum of the monthly averages because the grazing periods are not uniform.
[4] Average period of 10 days for the four seasons that the cattle were started on pasture in May.
[5] Average period of 21 days during four seasons that the cattle remained on their pasture in September.
[6] Loss for 30 days one season, 1916, the only year the cattle finished the season on their pasture.
[7] Average period of 12 days during three seasons that the cattle were started on pasture in May.

STUDY OF THE NATIVE VEGETATION

A comparatively large number of species of plants grow on the prairie in this region, but only 25 or 30 of them are important to grazing, and 4 of these produce approximately half of the forage. Some species are important to the grazier because cattle like them and eat them, while others are important because cattle do not eat them and they flourish to the disadvantage of those that the cattle do eat. The species of little grazing value may be favored by overgrazing because cattle will not eat them.

The dominant plant species in this region are blue grama grass (*Bouteloua gracilis*), western needle grass (*Stipa comata*), nigger wool or bull sod (*Carex filifolia*), and western sedge (*Carex heliophila*). Other species that are common and important in relation to grazing are *Artemisia gnaphalodes*, *Koeleria cristata*, *Solidago pulcherrima*,

FIG. 9.—Native vegetation in the 70-acre pasture at the Northern Great Plains Field Station on July 15, 1922

Artemisia dracunculoides, *A. frigida*, *Echinacea angustifolia*, and *Aristida longiseta*. The native vegetation of this area has been more fully described by Sarvis.[17]

The native vegetation in this section covers approximately 60 per cent of the ground, *Bouteloua gracilis* covering about 20 per cent and *Stipa comata* about 10 per cent. These are the most valuable grazing species. The vegetation in the 70-acre and the 30-acre pastures on July 15, 1922, is shown in Figures 9 and 10, which show the greater development of *Artemisia frigida* in the overgrazed 30-acre pasture.

Definite studies of the native vegetation have been followed since the grazing experiment was established. The details and results of these studies are fully discussed in Department Bulletin No. 1170.[18]

[17] Sarvis, J. T. Composition and density of the native vegetation in the vicinity of the Northern Great Plains Field Station. *In* Jour. Agr. Research, v. 19, p. 63–72, 2 fig., pl. 12–14. (Literature cited, p. 71–72.)

[18] Sarvis, J. T. Effects of different systems and intensities of grazing upon the native vegetation at the Northern Great Plains Field Station. U. S. Dept. Agr. Bul. 1170, 46 p., 11 fig., 9 pl. 1923. (Bibliographical footnotes.)

A brief discussion of each method and its results follows. The term "quadrat" in this discussion, unless otherwise specified, refers to an area of ground 1 meter (39.37 inches) square.

Mapped quadrats.—In these quadrats, all species of plants are indicated on a chart drawn to scale. Single plants are designated by symbols, and plants that grow in bunches or mats are drawn in outline and designated. Maps were made in the four continuously grazed pastures in 1915. The same quadrats have been mapped since that time. These quadrats are located in the open pastures and are therefore subjected to grazing. The mapped quadrats serve as permanent records of the composition of the vegetation. They show the relationship of the different species of plants, especially those that grow in mats (as blue grama grass), and bunches (as western needle grass). They show something of the effects of graz-

FIG. 10.—Native vegetation in the 30-acre pasture at the Northern Great Plains Field Station on July 15, 1922. The white plants are *Artemisia frigida*

ing on different species. While maps have been made to show all species in the quadrats, during recent years the maps have been drawn to show only blue grama and western needle grasses. These are the most important grazing grasses, and it is difficult to keep a record of them any other way. The quadrats mapped in 1922 indicate that western needle grass has been reduced by the severe grazing in the 30-acre pasture.

List quadrats.—The records of these quadrats are made by counting and recording the number of individual plants of species that grow singly or in distinct bunches. It is possible to keep such records on a comparatively large number of quadrats extending over the pastures. The list-quadrat records made in 1922 in the overgrazed 30-acre pasture show that *Artemisia frigida* had increased until it was from two to three times as thick as in any of the other pastures.

Clipped quadrats.—This name was adopted from the method of removal of the vegetation, which was cut or clipped close to the ground with a pair of roaching shears. In no case were the plants cut below their crown. The aim has been to cut all plants uniformly close to the ground, closer than they would be grazed by cattle. The plants were divided into different groups at each clipping. The clipping was done at different periods varying from 10 to 40 days, and annually, or at the end of the season. In 1919 a set of quadrats was added for the removal of the vegetation every two years. The clipped quadrats plainly show that the most active growth and greatest production of the vegetation as a whole is in May and June, the period during which the cattle make their greatest gains. *Bouteloua gracilis* is the species most resistant to clipping. Quadrats clipped at 10-day intervals were discontinued at the close of 1921. During 1922 *Bouteloua gracilis* made a fair growth on them, and a few plants headed out. *Stipa comata* is the species least resistant to clipping. It has entirely disappeared from the frequently clipped quadrats.

Isolation transects.—These areas were 40 feet wide and 300 feet long when first established. They were fenced when the pastures were started. One transect was located in the 30-acre pasture, one in the 100-acre pasture, and one in division B of the rotation pasture. On one side of the fenced area a unit 20 feet square was closed to grazing each year. On the opposite side a like unit was opened to grazing. The units in the center were never grazed. The transect in the 30-acre pasture shows the points of most value. The units on each side that have been grazed the longest show the largest number of plants of *Artemisia frigida* per unit area. In the units not grazed the plants of *A. frigida* remain normal in number and are not as coarse as those in the open pasture.

Photographs.—Views of the vegetation and cattle have been taken each year since the grazing experiment started in 1915. Photographs are of unusual value in connection with this experiment, as they bring out certain points and illustrate features that do not lend themselves readily to description or measurement.

Field notes.—Notes on the growth of the native vegetation are recorded each year. The time that any species starts growth in the spring is influenced by the season and may vary widely from year to year. There is also a wide variation between species in the time of starting growth. *Bouteloua gracilis* does not start its spring growth as early as most other grasses. *Stipa comata* and *Koeleria cristata* are the earliest grasses to start growth in the spring.

Other investigations which were carried on as a part of the grazing experiment were a mowing experiment, field germination tests of grass seeds, seeding experiments in the native sod, and soil-moisture determinations.

The acre units of the mowing experiment were so arranged that 3 acres were mowed each season and 3 acres in alternate years. The yield of hay from all units has been low, but the units mowed in alternate years have produced approximately twice as much hay per acre as those mowed every year. The hay from the two-year units was not of as good quality as that from the one-year units, as about one-third of its weight was composed of the old growth of the previous season.

With the exception of a few species, the germination of all grass seeds planted in the field was low. *Bouteloua gracilis* produced only a few plants. *Stipa viridula* showed a high germination.

Forage plants of different kinds were seeded in the native sod. Seedings were made by disking the sod and by scattering seed in the grass without disking. In no case during any season that trials were made was any stand obtained. From the trials made it appears that it is not possible to get a stand of any forage crop in the native sod without breaking it. In 1921 a field of 35 acres was broken in May and seeded to bromegrass. The season of 1921 was dry during the summer, but a good stand of bromegrass was obtained, it producing 1 ton of hay per acre in 1922.

Soil-moisture determinations were made each year in the different pastures. The data show that the native vegetation was practically dependent upon the current precipitation, as the soil was dry during most of the summer each season.

CONCLUSIONS FROM THE GRAZING EXPERIMENT

On the basis of the results from 1916 to 1922, inclusive, the following conclusions are drawn. These conclusions are based on the gains of the cattle and the condition of the native vegetation as affected by the different intensities of grazing.

The 100-acre pasture, grazed at the rate of one 2-year-old steer to 10 acres, is larger than necessary. This pasture has produced an abundance of feed, which has allowed the cattle to make nearly the maximum gains. Since the pasture is undergrazed, the native vegetation has not been injured by intense grazing; neither has the vegetation been benefited by the light grazing. Such plants as white sage (*Artemisia gnaphalodes*), green sage (*A. dracunculoides*), and purple coneflower (*Echinacea angustifolia*) make greater growth in the 100-acre pasture because they have been but slightly disturbed by grazing.

The 70-acre pasture, grazed at the rate of one 2-year-old steer to 7 acres, provides approximately the acreage required in this region for a system of continuous grazing. The cattle made the best gains in this pasture, but the native vegetation is not as completely utilized as under the system of deferred and rotation grazing.

The 50-acre pasture, grazed at the rate of one 2-year-old steer to 5 acres, is not large enough to produce sufficient feed to allow the cattle to make maximum gains. Pasture sage (*Artemisia frigida*) has increased in this pasture because of the close grazing. This pasture is overgrazed, as indicated by low gains of the cattle and the increase of *A. frigida*.

The 30-acre pasture, grazed at the rate of one 2-year-old steer to 3 acres, is severely overgrazed. It has not produced enough feed to carry the cattle for five months. The cattle in this pasture have made the lowest gains per head. The small acreage of the pasture has resulted in a high gain per acre. The native vegetation has been weakened by the heavy grazing. Pasture sage has increased more in this pasture than in any of the others. The cattle will not eat this plant, and the grazing capacity of the 30-acre pasture has been reduced by its increase. This plant also grows larger here than in any of the other pastures.

The 70-acre deferred and rotation pasture during the three years from 1920 to 1922, inclusive, has been grazed at the rate of one 2-year-old steer to 4.375 acres. This system of grazing has resulted in a high utilization of the vegetation. The gains of the cattle have been about 10 per cent below the best gains made. The vegetation in this pasture has not been injured by the high degree of utilization. This was because the vegetation in the different divisions of the pasture was allowed to mature periodically before it was subjected again to grazing.

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